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REMBASS AIRBORNE REPEATER/PLATFORM ANALYSIS,(U)
APR 78 R F PERRICELLI, J V O'BRIEN

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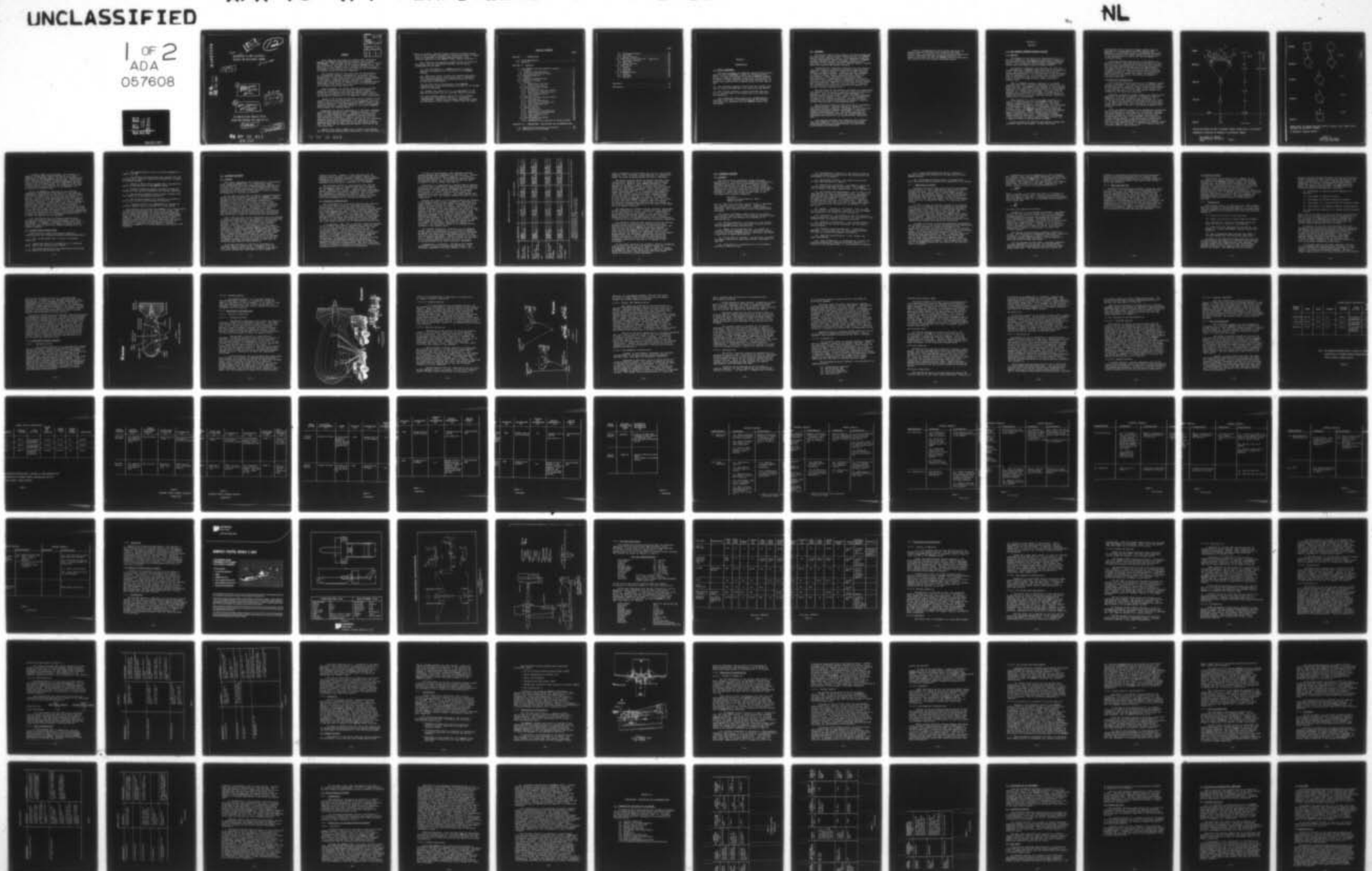

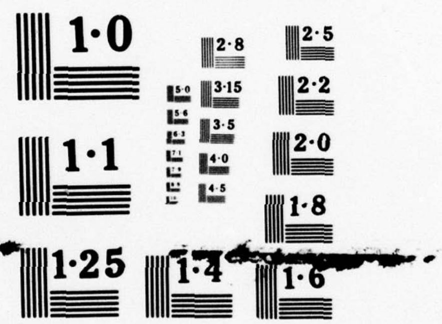

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REMBASS AIRBORNE REPEATER/PLATFORM ANALYSIS,

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SUMMARY

This study was initiated by a request from the Project Manager for Remotely Monitored Battlefield Sensor System (PM REMBASS). The Systems Analysis Office was tasked to analyze the alternatives available for an airborne REMBASS relay. The specifics of the analysis were to address the general design philosophy of the repeater, and the viability and acceptability of possible airborne platform candidates.

The ultimate goals of the study were the determination of a recommended repeater configuration and design, and a determination of the relative merits of particular platform alternatives. These goals were to be achieved through review of the possible repeater designs, analysis of platform operational characteristics compatibility with REMBASS mission requirements, and evaluation of the relative effectiveness of the repeater/platform combination.

Both Government and private industry sources provided technical information in the areas of repeater design parameters and airborne platform performance capabilities. It was this information that provided the technical base for the subsequent evaluation of the competing viable alternatives.

Based on the information obtained, and as a result of the analysis and evaluation performed, it was concluded that the general concept of employing an airborne REMBASS relay is both valid and desirable. The implementation of an airborne relay system would have a beneficial impact on the overall REMBASS effectiveness and responsiveness.

Regarding the relative performance of the major candidate platform types (manned aircraft, tethered aerostats, or Mini RPVs), it was determined that a compatible, non-dedicated, manned aircraft (such as the SLAR OV-1D) would be the most cost effective alternative. Further, should the use of a manned aircraft prove unacceptable, then the use of a system of tethered aerostats was determined to be preferable to one employing Mini RPVs. These conclusions were based primarily upon the impact of the Operating and Support portions of the life cycle cost.

Based on the system communication channel requirements and the available payload/space limitations, it was concluded

that any airborne repeater design eventually produced should be of a multi-channel configuration, and should employ a higher level of technology (electronic miniaturization) than currently employed in the REMBASS single channel repeaters.

As a result of the evaluations made during the course of this study, and the conclusions reached, the following recommendations are made:

(1) The development of a REMBASS airborne repeater system be incorporated into the goals of the REMBASS program.

(2) Additional effort be directed towards developing a more detailed airborne relay system plan of operation, to include determination of projected battalion level system usage requirements.

(3) For the case of concentrated corps REMBASS communication, a detailed analysis of threat to the system should be performed.

(4) Pending the results of (3), the employment of the SLAR OV-1D aircraft for the platform should be pursued.

(5) The airborne repeater should be a multi-channel configuration (consistent with (2)), utilizing a "simultaneous" receive and retransmit operational format, and employing a hybrid design to reduce size and weight.

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SECTION I

INTRODUCTION

1.0 STUDY BACKGROUND

The Project Manager for Remotely Monitored Battlefield Sensor System (PM-REMBASS) tasked the Systems Analysis Office to study the problem of placing a REMBASS repeater aboard an airborne platform situated over the battlefield in terms of viable repeater and platform alternatives. To answer this question the following objectives were addressed:

(1) The candidate repeater alternatives for possible use with an aerial platform had to be identified and defined.

(2) The various candidate airborne platforms that are or will be available in the future had to be identified and evaluated.

Upon addressing these objectives, recommendations relating to the type of airborne platform and repeater that should be considered for the REMBASS mission were determined.

2.0 APPROACH

The initial step of this analysis concerned determining the operational characteristics associated with the REMBASS Sensor/Airborne Repeater System. With assistance from the US Army Intelligence Center and School (USAICS) the REMBASS Airborne Repeater Concept was proposed addressing the deployment of an airborne platform, repeater channel requirements and repeater emplacement concepts.

Considering the information obtained from the exercise above and technical assistance provided by agencies/firms engaged in repeater design, a number of airborne repeater alternatives were proposed. Each candidate was addressed in terms of design, channel configurations (single and multichannel), power requirements and weight/volume characteristics. Consequently, a substantial portion of the effort was directed towards determining the appropriate platform interface parameters for differing repeater designs and configurations. This data was then used to establish the acceptability/feasibility of particular repeater and airborne platform configurations.

The next phase of the analysis evaluated the capabilities and desirability of the major airborne platform alternatives available. Each platform category was addressed in a separate section of the report. Where a platform dominated its particular category it was chosen as the representative alternative for further evaluation. The major platform categories evaluated included Tethered Aerostats, Remotel-Piloted Vehicles (RPV's) and Manned Aircraft.

Each platform alternative was evaluated by considering its characteristics: payload capability, number of platforms required, endurance, vulnerability, survivability, operational altitude, support requirements, reliability, schedule considerations, etc. To further evaluate the representative candidate platform the disadvantages and advantages associated with its operation were elaborated upon.

The airborne platforms that dominated each category were then compared. A matrix was prepared describing characteristics/repeater supportability and associated disadvantages and advantages.

Finally, recommendations were stated concerning the types of airborne platforms that dominated the other alternatives. In conjunction with the platform alternatives chosen, recommendations were developed concerning the repeater that would satisfy the REMBASS mission requirements and interface with the airborne platforms chosen.

SECTION II

ANALYSIS

1.0 THE REMBASS AIRBORNE REPEATER CONCEPT

1.1 General

The purpose of this section of the analysis is to provide information concerning the operational characteristics associated with the REMBASS Sensor/Airborne Repeater System. This information was provided by personnel from the US Army Intelligence Center & School (USAICS).

As currently conceived, each division will make use of approximately 10 REMBASS teams operating at the battalion level. Each team would provide data to its battalion concerning enemy activity in their portion of the division's area of responsibility. It is likely that this data would also be monitored at the division level to provide an overall picture of enemy activity across the entire division area.

When the REMBASS system is employed in its normal operating mode, and to provide information directly at the battalion level, the REMBASS team assigned to the battalion would have the capability of monitoring up to sixty sensors deployed in a sensor field generally from 0 to 15 KM but possibly up to 50 KM beyond the FEBA. Although up to 60 sensors may be monitored, the capability of an operator to assimilate data in an active field may require a practical limitation of 10-20 sensors.

When deployed in a very short range situation (i.e., sensor 0-15 KM from monitor) the REMBASS sensor would transmit messages directly to the monitor. For those instances where information regarding enemy activity beyond a 15 KM range is desired (i.e., information for use at Brig/Div level), the REMBASS sensors would be employed in conjunction with REMBASS repeaters to relay the message back to the monitor. Such a system could be used to monitor enemy activity up to 150 KM beyond the FEBA (essentially Div level info). Consequently, the REMBASS could conceivably be used to monitor enemy activity over a range of from 0 to 150 KM beyond the FEBA.

We may consider two possible applications representing different uses of the system. In the first case,

representing typical battalion usage, sensors would be deployed up to approximately 50 KM beyond the FEBA. Employed at those shorter ranges, the REMBASS data should allow more accurate and timely response of the battalion to the changing flow of battle and the realignment of unfriendly forces.

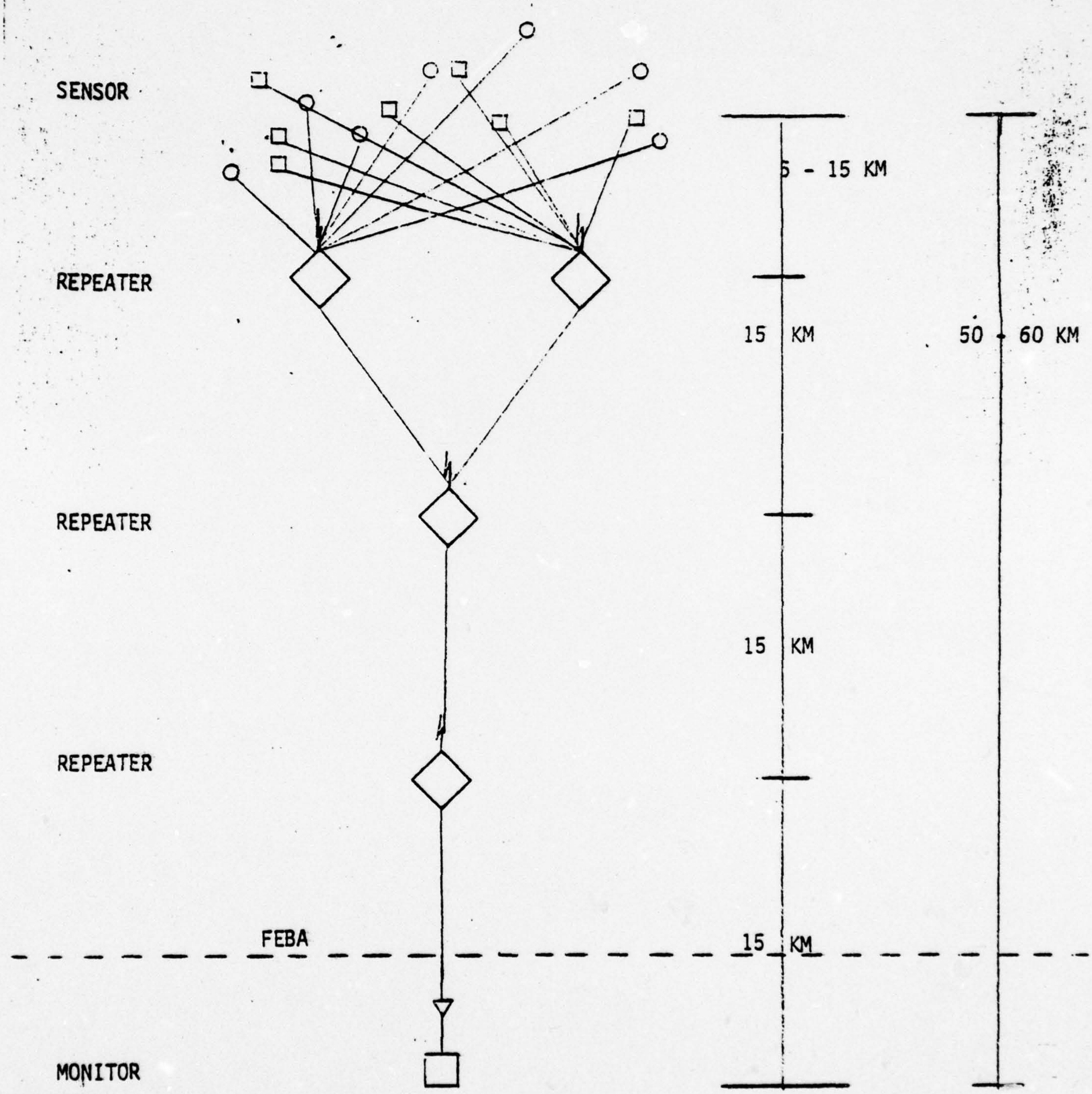
The second possible application of the system, as previously noted, involves obtaining information on enemy activity that is predominantly of division level interest. Data provided disclosing enemy activity and movements in the region from 50 to 150 KM beyond the FEBA could be invaluable to the division in anticipating and reacting to enemy initiatives. Effective use of this information might significantly reduce the element of surprise in hostile action, and allow a more efficient usage of available resources.

1.2 Technical Considerations

Use of ground emplaced repeaters in the REMBASS imposes certain constraints. In order to insure a reliable link between the various elements (sensor, repeaters and monitor), it is necessary to insure that links are not greater than 15 KM long, and that a line of sight exists between the transmitting and receiving components.

Assuming a separation between sensors and repeaters of a maximum of 15 KM, and a repeater to repeater or monitor range also of 15 KM, the sensors and repeaters, for battalion level data, might be deployed as shown in Figure 1. To employ the system over this range then (using only ground level repeaters), would require up to three repeater links from sensor to monitor, each having acceptable line of sight.

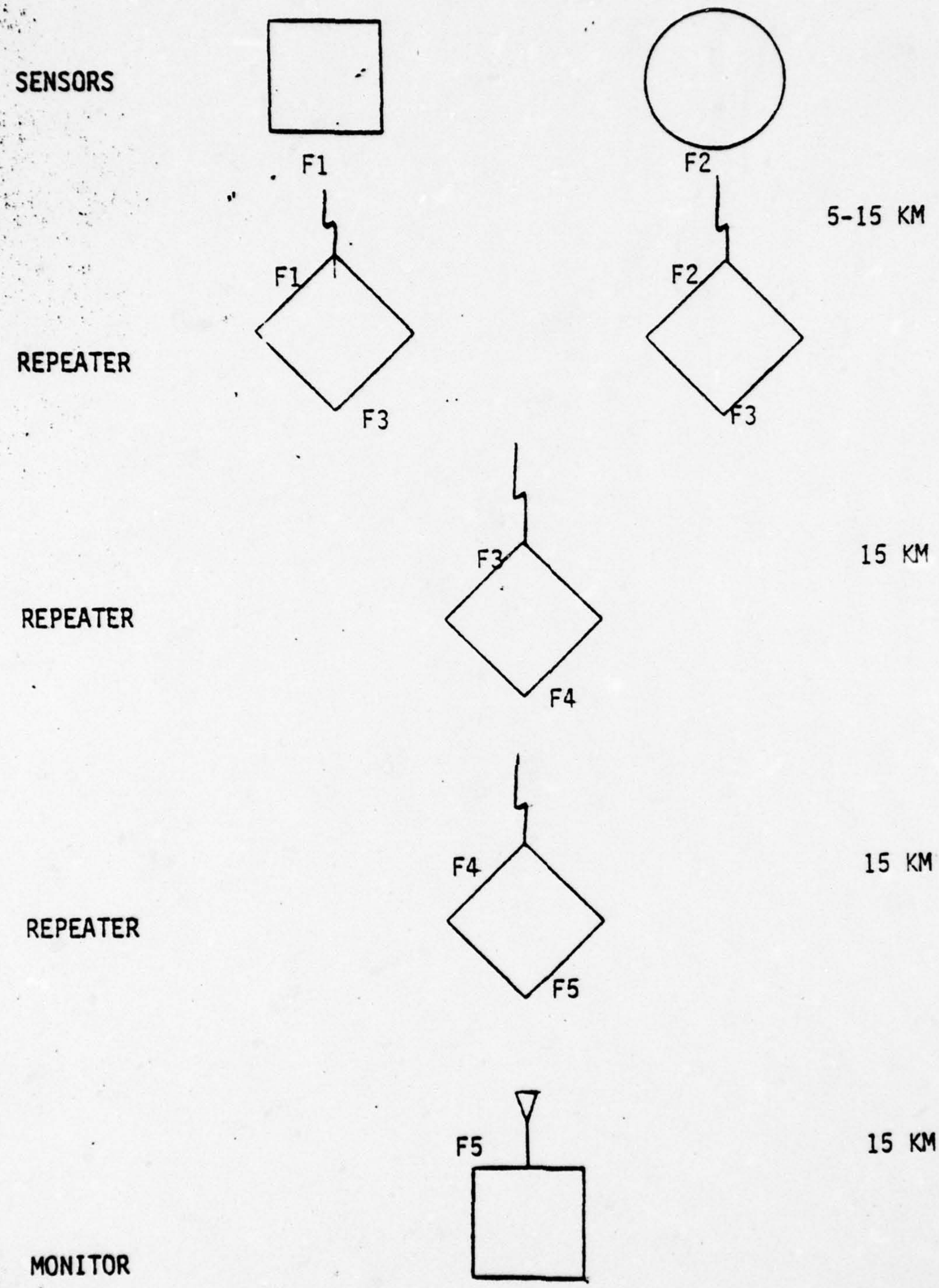
Since the repeater reception and transmission frequencies must be different to eliminate any "ring around" problems, the 50 KM deployment would make use of different channels as shown in Figure 2. Using the common path from the second repeater on back to the monitor, and allowing for a single spare channel, a team monitoring a single sensor field at a range of approximately 50 KM would require the use of six channels or six ½ channels (by dividing sensor ID's into high and low bands, it would be possible for two different teams to share channels).



CIRCLES AND SQUARES ARE USED TO REPRESENT SENSORS TRANSMITTING ON TWO DIFFERENT FREQUENCIES TO MINIMIZE THE PROBABILITY OF SUCCESSFUL JAMMING.

DEPLOYMENT OF SENSORS AND REPEATERS, BATTALION LEVEL

Figure 1



Numbers above the repeater designate receiver frequency, while numbers below designate the transmitter frequency.

F1 Represents frequency channel 1

Figure 2
CHANNELS ASSOCIATED
WITH 50KM DEPLOYMENT

A similar common path deployment, but extended to a range of 150 KM would require the use of up to twelve channels or ½ channels (again, the use of ½ channels would allow sharing) per REMBASS monitoring team. Considering that a division would have 10 teams, deployment and monitoring of all ten sensor fields at a range of 50 KM would require from 30 to 60 channels, and a deployment for data at 150 KM would require from 60 to 120 channels to be available in a division area.

Use of the REMBASS as described in the preceding paragraphs is predicated on availability of the required transmission channels and on the ability to achieve acceptable line of sight along the radio path from sensor to monitor. Insofar as long range applications are concerned, the availability of 60 to 120 channels (if all 10 sensor fields are employed) is questionable, and indeed the need to establish 11 RF links using line of sight from sensor to monitor might reduce the reliability of the system to unacceptable levels. Even in the shorter range applications (i.e., less than 50 KM) there is no assurance that the local terrain will be suitable for ground line of sight transmission. It is this concern over the ability to achieve acceptable line of sight and availability of transmission channels that provides the impetus for this analysis.

It is anticipated that an airborne repeater would increase the range of effective transmission from sensor to repeater, or repeater to repeater (perhaps from 15 up to 100-150 KM). In addition, the impact of adverse terrain conditions might be drastically reduced through use of an airborne repeater.

1.3 Airborne Relay System Goals

Listed below are some of the desired operating characteristics for a repeater/airborne platform combination.

a. The system should have a 24 hour all-weather capability.

b. Sensor data should be transmitted on a continuous basis, rather than using periodic updates.

c. The system should allow for simultaneous monitoring of all sensors in the division area.

d. The system should be able to receive messages at a range of 100 KM.

e. The airborne platform system will operate over the division area, this will reduce its vulnerability to enemy air defense systems.

f. Manned or RPV platform systems under consideration should be non-dedicated to the REMBASS system.

g. Separate analog and digital repeater systems are desirable (this analysis addresses only digital repeaters).

h. The airborne repeater should be multi-channel with the capability of simultaneous operation.

i. The airborne repeater will operate in conjunction with hand, air and artillery emplaced repeaters.

j. A growth potential for commandability through the airborne repeater must be provided for in the system.

An airborne relay utilized with REMBASS could significantly increase the effectiveness and value of the system. Due to the reduced requirement for ground emplaced repeaters, and the resulting increase in reliability of communication lines, the overall system availability should be favorably affected. In addition use of an airborne relay would provide for more reliable links, in areas with poor terrain characteristics or over long ranges, and could also be beneficial in reducing the total number of channels required as compared to a system employing only ground level repeaters.

2.0 AIRBORNE REPEATERS

2.1 General

The overall performance and capabilities of the airborne relay augmented REMBASS are, to a significant extent, directly dependent upon the repeater-platform compatibility. To achieve an optimal level of effectiveness would require tailoring the design requirements and capabilities of the repeater and the platform to each other in order to achieve as harmonious an interface as possible.

At the time of this study, no specific repeater/platform design had been developed or proposed for REMBASS. Indeed, the goal of this study is essentially to provide preliminary information prior to any such design determination. Mention is made of this fact to point out that it was necessary to perform this study without certain detailed information as to how and to what extent such an airborne relay system would be used. Consequently, in order to provide information that would ultimately be useful, despite the inherent uncertainties involved, this analysis was performed by evaluating repeater/platform combinations that would cover a range of utilizations and requirements.

One of the principal factors associated with this analysis involved the capabilities of the potential airborne platforms, as affected by the physical requirements of the airborne repeater. In order to evaluate a particular repeater/platform interface, it was necessary to arrive at an estimate of the physical characteristics of the airborne repeater(s). Currently proposed REMBASS repeaters were not envisioned as being employed with the airborne platforms now being considered. The current REMBASS repeater designs are of single channel configuration and, since they were never intended to perform the specific mission being considered in this analysis, are too bulky to be suitable. Consequently, one of the initial steps in this study was to propose candidate airborne repeater alternatives and determine their physical characteristics.

No attempt was made to identify an acceptable or "optimum" channel configuration. Personnel at the US Army Intelligence Center and School (USAICS) were unable to provide information concerning the exact number of

channels required. However, it was indicated that the repeater should probably be of multichannel design with a maximum of ten channels available. Based on this parameter, configurations employing 1, 2, 5 and 10 channels were addressed as the potential candidates for the REMBASS.

The following portion of this analysis will describe the alternative types of repeaters that were considered for the REMBASS airborne relay. Characteristics such as channel configuration, weight, volume and power requirements were compiled for alternative repeaters. This information was subsequently combined with technical data for the candidate airborne platform systems to evaluate the capability and acceptability of the various combinations.

2.2 Repeater Configurations

The requirement for an airborne repeater that would be suitable with various possible platforms introduces a complicating factor involving cost/technology tradeoffs. At one extreme it would be possible, by sacrificing any weight and volume constraints, and by using technology comparable with other REMBASS equipment, to obtain an inexpensive, but large, airborne repeater. On the other hand, the limited payload capabilities of some platforms might require greater adherence to the weight and volume constraints, resulting in the use of more advanced technology to produce a small and light weight repeater, but of considerably greater cost.

It is apparent, then, that to provide a complete analysis of an airborne relay system, consideration should be given not only to the potential platforms available, but also to the performance of these platforms with various conceivable relays. Any ultimate decisions as to the desirability and specification of an airborne relay should be made in the light of information covering a complete spectrum of possible repeater/platform combinations. Consequently, a substantial portion of the effort involved in this study was addressed towards determining the appropriate platform interface parameters for differing repeater designs and configurations. This data could then be used to establish acceptability/feasibility of particular combinations prior to evaluation of performance.

In light of the preceding, four candidate airborne repeater designs were considered in this analysis. Further, each design was also varied in terms of 1, 2, 5 and 10 channel configurations. The alternative repeater designs are described below, and in addition the data has been arranged in a matrix format (see Table 1).

Alternative 1 is described as a Queuing Hybrid Repeater. As with all the alternatives, signals are received from the field-emplaced sensors and are retransmitted to a receiver-monitor unit. In this particular design the messages are received and stored (lined up as in a queue) for transmission as soon as possible. The sensor message must remain in line until the channel becomes free and it can be transmitted.

Queuing the signals in this fashion permits the repeater to be designed using a single transmitter, operating on a single channel (although the number of channels upon which signals are received may be varied). The drawbacks of a queuing repeater are that the limited size of the queue (number of messages held simultaneously) may result in some signals being lost because the queue is already filled. In addition, use of a queuing repeater would require some additional equipment for coding and uncoding the sensor messages according to the original channel of reception. This is made necessary by the fact that the channel of the signal is a basic part of the sensor identification (sensor ID by number and channel), and a queuing repeater sends all signals on one channel regardless of channel of reception. The additional coding of the message permits recovery of the original data.

The "hybrid" designation indicates that the repeater design involves miniaturization of electronic components by employing a more advanced integrated circuit technology. Therefore, the weight and volume characteristics of the unit are greatly decreased. However, because of the high cost of hybrid components it can be expected that the price of the repeater would be greater than that of a unit utilizing standard solid state electronic components.

Consequently, alternative 1 represents the optimal obtainable in terms of reduced size and weight. The electronic components have been reduced in size, and a

REMBASS Airborne Repeater Alternatives

Alternative	Characteristics	Repeater Channels 1	2	5	10
Alt 1	Weight	3.17 LBS	3.40 LBS	4.34 LBS	5.35 LBS
Queuing Hybrid	Volume	9 in^3	10.5 in^3	18 in^3	26 in^3
Repeater Concept	Power/24 hrs	.36 amp-hrs	.64 amp-hrs	1.50 amp-hrs	2.94 amp-hrs
Resdel Eng Corp					
Alt 2	Weight	6.1 LBS	10.1 LBS	19.6 LBS	34.6 LBS
Receive and	Volume	300 in^3	440 in^3	809 in^3	1470 in^3
Transmit Repeater	Power/24 hrs	1.03 amp-hrs	1.75 amp-hrs	3.92 amp-hrs	7.50 amp-hrs
Concept - non hybrid					
RCA					
Alt 3	Weight****	3.17 LBS	3.9 LBS	6.25 LBS	9.5 LBS
Receive and Transmit	Volume ***	9 in^3	14.0 in^3	32.0 in^3	57.5 in^3
Repeater Concept	Power 24/hrs	.36 A-hrs	.72 A-hrs	1.8 A-hrs	3.6 A-hrs
Hybrid					
PM REMBASS					
ALT 4	Weight **	6.1 LBS	9.6 LBS	17.5 LBS	29.9 LBS
Queuing Non-Hybrid	Volume *	300 in^3	418 in^3	721 in^3	1270 in^3
Repeater Concept	Power 24/hrs	1.03 amp-hrs	1.72 amp-hrs	3.79 amp-hrs	7.20 amp-hrs
PM REMBASS					

*Obtained by subtracting volume of XMTR/Synthesizers/Store & FWD Logic Modules (conservative)
**Assumed proportional to volume
***Obtained by adding XMTR volume (23.5 in^3/XMTR)
****Obtained by extrapolating resdel wt/volume date

TABLE 1

single transmitter is used rather than one for each channel received. This "optimum" is obtained only at a penalty of higher costs and increased system electronic complexity.

The second repeater design alternative employs a more "conventional" approach (i.e., the design and technology are similar to those of other REMBASS equipment). The repeater is designed to employ a receive and transmit concept for each channel, and the design utilizes standard solid state electronic components. Use of this concept allows the sensor messages to be received and transmitted almost simultaneously. It is intended to approximate a "real time" system transmitting sensor messages without having the delay of waiting in a queue. The advantages of this alternative are that its design is compatible with the remaining REMBASS equipment, and that, as a result of this, the cost of such a repeater should be minimal. The principal disadvantage associated with this design is its relative bulkiness, especially in the case of the larger multiple channel repeaters.

The remaining two repeater designs represent compromises between alternatives 1 and 2. Alternative three functions in the same manner as alternative 2 (i.e., conventional multi-channel receive and transmit), but employs a hybrid design to achieve reduced weight and volume. Finally, alternative four is a queuing repeater (as with alternative 1) constructed with standard solid state electronic components.

The estimated technical data associated with the various repeater design alternatives was obtained from sources possessing the required expertise in appropriate areas, and familiar with the basic REMBASS system and equipment. Those sources which provided the basic data used in this study were the PM REMBASS, the Combat Surveillance and Target Acquisition Laboratory (CSTA-ECOM), RCA in Burlington, Massachusetts, and the Resdel Engineering Corporation, Arcadia, California. The information provided by the contractors (RCA and Resdel) were informal engineering estimates provided as a courtesy at no expense to the government.

As previously indicated the estimated technical parameters used in this analysis, for each repeater design and configuration, are presented in Table 1. Again, it should be remembered that these figures are estimates for equipment which does not exist, and as such may vary from actual values of eventually fielded equipments.

3.0 AIRBORNE PLATFORMS

3.1 General

The overall final performance capabilities and desirability of an airborne relay system are predominantly determined as a result of the characteristics of the platform selected for the system. A complete investigation of the viability of an airborne relay system then requires that the entire spectrum of possible platforms be considered. During the course of this study, an effort was made to obtain data on and evaluate each of the following major platform categories:

Aerostats
Remotely Piloted Vehicles (RPV's)
Manned Aircraft

Each of these major platform classifications is addressed in a separate section of this report. Comments on additional types also considered, but deemed essentially unsuitable, are provided in the section on miscellaneous platforms.

The overall performance capabilities of an airborne relay system, based on each of the candidate platform types, were evaluated by considering the following set of characteristics:

(1) Payload Capability - the ability of the airborne platform to support the size and weight required by the various REMBASS repeater alternatives.

(2) Number of Platforms Required - the number of airborne platforms/repeaters that are required to support a 24 hour divisional REMBASS mission requirement and insure a high level of system availability.

(3) Loiter Time of Platform - the time that a platform can remain airborne and operational before replacement is required.

(4) Vulnerability - susceptibility of the airborne platform to hostile attack.

(5) Survivability - ability of the airborne platform to withstand hostile military action and continue with the performance of its mission.

(6) Operational Altitude - the height above ground at which the platform will operate.

(7) Reusability of Platform - the degree to which the relay/platform combination can be reused. The judgment will be based on the least reusable part of the combination.

(8) Set Up/Tear Down Requirements - set up time is the time required to reach an operational status, and deploy a repeater/platform, from the transportation configuration. The planning time required prior to emplacement is not included in this estimate. (Planning time is assumed to be approximately equal for all alternatives). Tear down time is the time required to go from an operational status to the transportation configuration for movement to the next site.

(9) Support - estimate of the support, both in terms of the personnel and equipment, required for the deployment and operation of the relay/platform combination.

(10) Reliability - the probability that the relay/airborne platform will perform its mission for the period of time intended under the proposed operating conditions.

(11) Schedule Considerations - the current status of the airborne platform system development and anticipated future program.

(12) Technical Risk Consideratons - a qualitative assessment of the probability that the airborne platform will fail to complete development successfully.

(13) Physical Characteristics - size, weight, and power availability.

(14) Area of Operation - a determination of where the airborne platform will perform its mission and how, in relation to the division area, it is anticipated to operate.

(15) Dedicated/Non-Dedicated System - whether or not the platform/relay system will be identified with the REMBASS mission.

(16) Environmental/Meteorological Considerations - what limitations must be placed on the operation of the system.

3.1.1 Operational Altitude

The major difficulty associated with the establishment and reliability of radio links has not been one of lack of transmitting power, but rather the requirement for the existence of an acceptable radio line of sight between the transmitting and receiving elements. This limitation has its greatest impact when the system is used in areas of rough terrain, or over long ranges. The use of an airborne relay could be of substantial benefit in alleviating this problem.

In order to reap the benefits claimed for an airborne repeater, it is necessary that the repeater be deployed so as to maximize the probability of establishing successful communication links. For both of the limiting cases (i.e., adverse terrain conditions and/or long ranges), the likelihood of establishing successful communication links with an airborne relay is a direct function of the altitude of the repeater. The greater the altitude of the relay, the greater the probability of establishing acceptable radio communication between the sensors and the monitor.

In order to be able to evaluate comparative performances and acceptability of the various repeater/platform combinations, it was first necessary to obtain an estimate of the operational altitude that would be required for the airborne relay. In view of the desirability of providing a considerably greater link length than that achievable with ground emplaced relays (approximately 15 KM), a baseline figure for evaluation purposes would be that altitude required for line of sight radio communications at a range of 100KM. The altitude necessary to provide a 150 KM link would also be used as an alternative figure. These ranges would cover use of the REMBASS system over both battalion and division areas of interest.

Information as to the propagation of radio frequency (RF) signals, under line of sight conditions, was provided by personnel at the PM REMBASS and at the Combat Surveillance and Target Acquisition (CSTA) Lab. According to this information, the distance to the radio horizon over a smooth earth, when the height h is very small compared with the earth's radius, is given with good approximation by

$$d = \left(\frac{3kh}{2}\right)^{\frac{1}{2}}$$

where h = height in feet above the earth, d = distance to radio horizon in miles, and k = ratio of the effective to the true radius of the earth. Rearranging this relationship, given the desired range (d), the required platform height (h) can be found from

$$h = \frac{2d^2}{3k}$$

with the units specified as before.

Through use of the preceding relationship, and making note of the fact that the average value of K in temperate climates is about 1.33 (i.e. 4/3), the required altitudes are determined after making the appropriate conversions (i.e., kilometers to miles). Following the procedure described, it was determined that an RF link of 100 KM would require the airborne relay to operate at an altitude of 1,930.5 feet (588.4 meters). Further, if it is desired to receive information at a range of 150 KM, then the relay would have to operate at an altitude of 4,343.6 feet (1,323.9 meters).

The figures determined above represent theoretical values. Any variations in atmospheric conditions, regularity of terrain, or differences in ground level elevation (different heights above sea-level) could be expected to alter the relay altitude requirement.

For the purposes of this study, a minimum acceptable altitude capability, with payload, for any particular repeater/platform combination was set at 2000 feet above ground level (AGL). Any repeater/platform combination

incapable of achieving the required altitude performance would be considered unsuitable for the airborne relay mission due to limited applicability. Altitude capability above the minimum performance requirement would be beneficial and desirable.

3.1.2 Power Availability

Various of the platforms considered, during the course of this study, have the capability of supplying the power required to operate the airborne relay configurations. For the remaining systems, the power required for each repeater configuration (as given in Table 1) would have to be supplied from another source (most likely a battery included in the payload). To insure a fair and complete comparison of the performance of different alternatives, the capabilities of various platforms were evaluated under a consistent set of constraints. For those cases where the platform was unable to supply the required electrical power, the performance capabilities were determined based on a payload that included the required batteries.

3.2 Aerostat Systems

This portion of the analysis will address the use of tethered and powered aerostats as potential airborne platforms for the REMBASS repeater system. The aerostat concepts that are available will be described, including their physical characteristics as related to the airborne repeater. In addition, the factors that affect the operational characteristics of these devices will be elaborated upon including weather, survivability, reliability, mission profiles, etc. A matrix has been prepared outlining aerostat characteristics and the ability to support the proposed repeater alternatives. The disadvantages and advantages associated with aerostat systems are also provided.

3.2.1 Introduction

The military conflict in Southeast Asia (SEA) created many new problems for the defense community. In particular, difficult problems developed concerning the existing sensor (radars)/communications equipment when confronted with such demands as:

(1) patrol activities for long durations.

(2) patrol activities in a dense jungle environment.

(3) "hit and run" tactics of the enemy making the enemy difficult to locate for counteraction.

(4) enemy artillery emplacements scattered and well hidden in a jungle environment, making counteraction difficult.

(5) use of designated demilitarized zone (DMZ) to initiate assault and infiltration by enemy units.

To assist in solving the problems described above the tethered aerostat was chosen as a suitable aerial platform to support sensor and communications relay payloads. The Advanced Sensor Office (ASO) of the now disestablished Advanced Research Projects Agency (ARPA) was tasked to perform the mission. The ARPA-ASO program furnished

readily available balloons/aerostats for test and evaluation by units operating in SEA. Following the SEA phases of the effort, programs were initiated to address development of a ruggedized, all-weather, aerodynamically shaped balloon system for use as a military aerial platform supporting sensor and communication payloads. The ARPA-ASO aerial platforms program accomplished the following:

(1) development of improved fabrics/laminants for aerostats

(2) development of improved tethers

(3) development of aerostat handling procedures

(4) development of a stable 200,000 ft^3 aerostat system

(5) development of an improved aerostat mooring system

(6) demonstrated operation of a tandem tethered aerostat system.

ARPA's activities ceased in 1975 with the Air Force assuming control of the aerostat program and existing equipment. The Air Force is attempting to utilize a tethered aerostat as a platform for a Moving Target Indicating (MTI) air defense radar system for detection and tracking of low flying aircraft approaching from over water.

In addition to the activities described above the Immigration and Naturalization Service (I&NS) is considering the feasibility of employing tethered and powered aerostats as elevated platforms for remote sensors in order to increase the detection and apprehension rate of illegal aliens crossing the US-Mexican border. The primary approach being considered is elevating an MTI radar, Forward Looking Infrared (FLIR) or Low Light Level Television (LLLTV) equipment in aerostats to monitor the flow of intruders through the border areas.

Of the many types of "balloons" available, the non-rigid aerodynamically shaped balloons (aerostats) are well suited to perform the sensor/communication mission. The aerostat can either be tethered or powered. The aerodynamic shaping ensures a low drag configuration and provides

vertical and horizontal control in a powered flight application. In addition, its inherent aerodynamic lift characteristics resist blowdown by high winds and provides supplemental lift to the powered systems. The natural (spherical) shaped balloon systems will not be considered because of their stability problems in high winds. The high drag and low aerodynamic lift inherent in spherical shapes and the instability associated with this type of design degrades the performance of these vehicles.

Both Raven Industries and the Sheldahl Corporation produce aerodynamically shaped balloons. Aerostats can be purchased off-the-shelf from Raven and are offered in three different model series operating from 500 ft AGL (above ground level) to 5000 ft AGL. Each aerostat is fitted with a rigid 4 ft tail assembly and can operate in winds up to 40 mph. The Sheldahl Corporation also manufactures aerostats for both tethered and powered applications. Sheldahl has produced a family of operational tethered aerostats and will build systems to meet customer requirements. The vehicles that they currently produce are large compared with the Raven systems and are capable of operating continuously in 20-90 knot winds to a maximum altitude (for some models) of up to 15,000 feet above sea level.

3.2.2 Alternative Aerostat Systems

3.2.2.1. Tethered Aerostat

The tethered aerostat is an aerodynamically shaped balloon attached to a ground cable (tether) and capable of serving as a stable airborne platform. Its aerodynamic design provides the vehicle with the capability of operating under various weather conditions including high winds (see Figure 3). The size of the aerostat (volume) is dependent upon the total weight of the vehicle, tether line, payload, and the operational altitude required. A non-rigid interior structural design permits the aerostat to be operated with a minimum number of personnel and equipment. While in the field an inflated aerostat can be transported by either a truck or helicopter. The aerostat can be inflated with helium or hydrogen depending on economic and operational considerations.

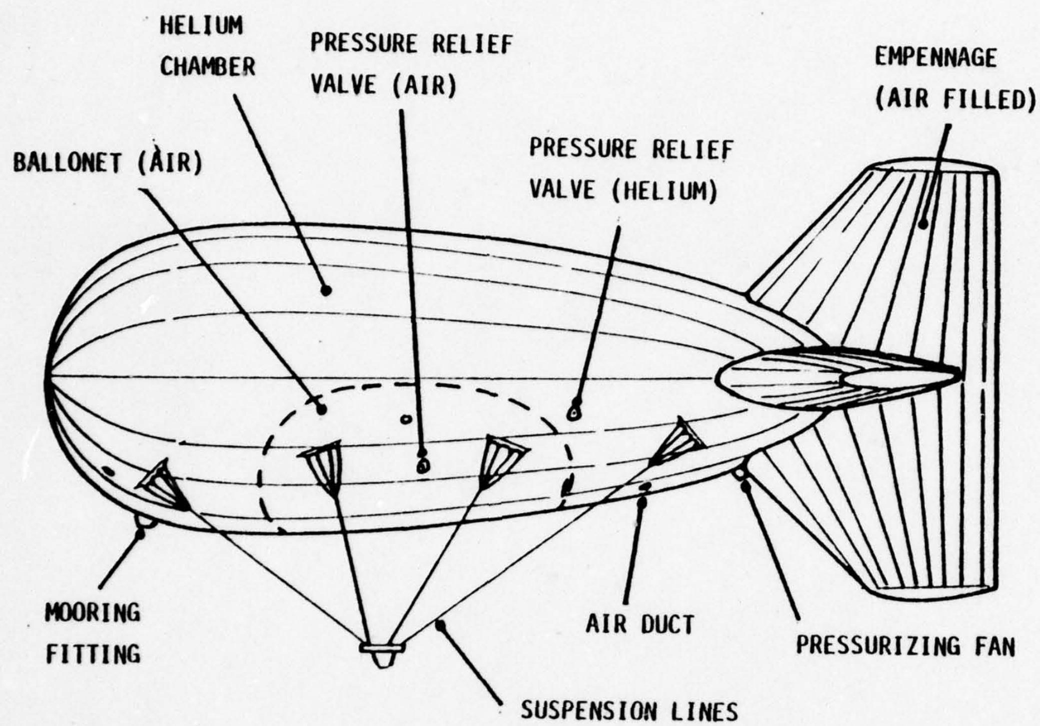


FIGURE 3

AEROSTAT NOMENCLATURE

3.2.2.2 Powered Aerostat

The powered aerostat is of the same design as the tethered model, however, it is capable of operating under its own power at low air speeds. It is larger in size than the tethered vehicle for it must provide the lift necessary to support the power source, navigational/control equipment, fuel and payload.

3.2.3 Operational Considerations

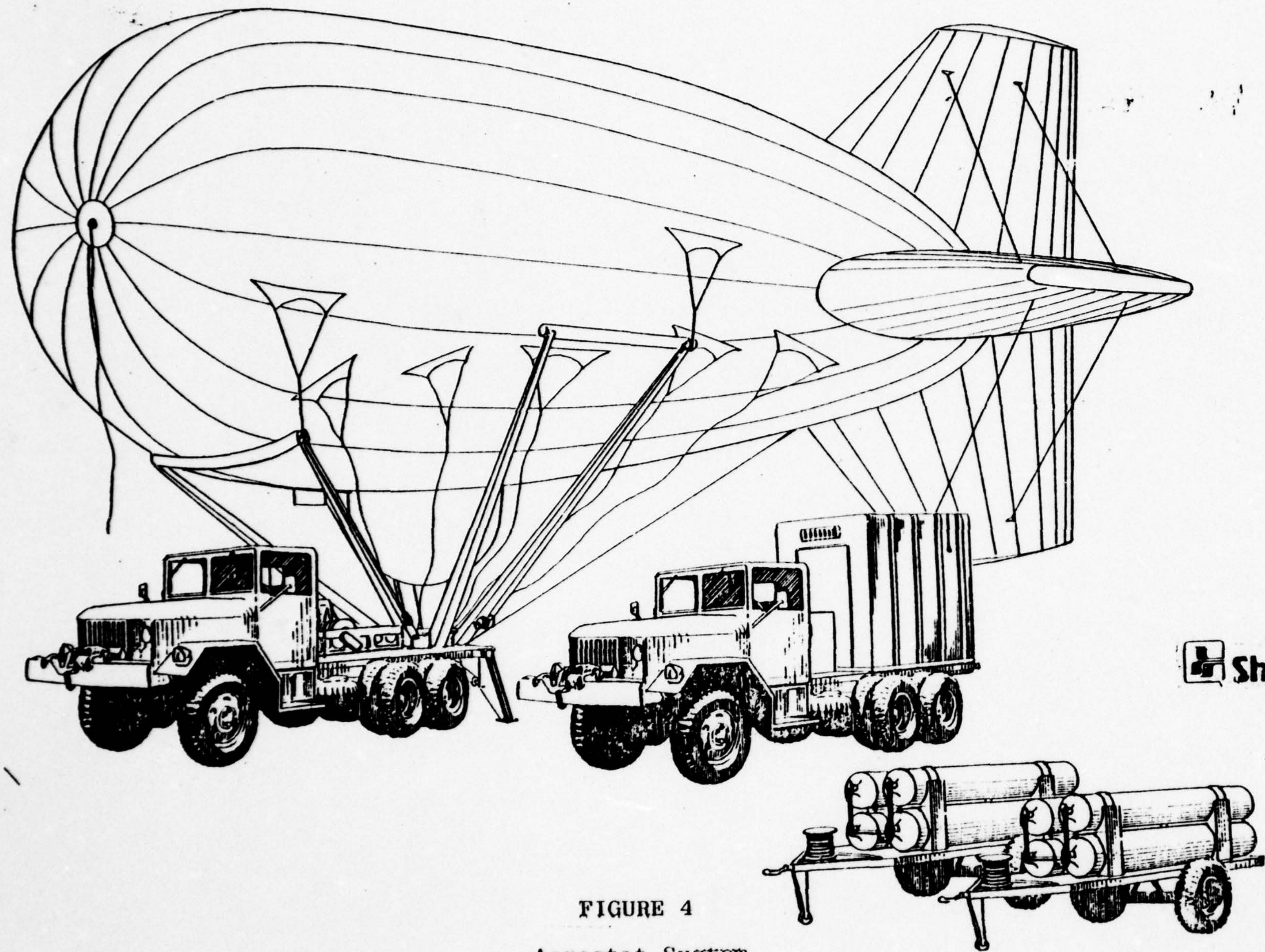
3.2.3.1 Concept of Operation

3.2.3.1.1 Tethered Aerostat

The System is deployed on two trucks (see Figure 4) providing a highly mobil deployment capability. One truck (conventional 2½ ton trucks can be used) contains the aerostat, winch, tether cable and all the other necessary aerostat support equipment including the repeater package. The other vehicle houses the command and control center. Helium is supplied in pressurized steel cylinders mounted on two trailers with enough to inflate an aerostat twice.

The aerostat is stored on a drum within a container. Torque is applied to the drum as the aerostat is inflated, this prevents the partially inflated aerostat from becoming flaccid and unmanageable in the wind. As the aerostat is inflated, it is pulled into position upwind onto a "V" shaped mooring boom located on the truck. A pressurizing fan is then attached to the aerostat and used to fill the fins and ballonet with air. The fan remains with the aerostat in flight to control the differential pressure changes caused by atmospheric pressure and temperature variations.

After inflation, the relay package and tether cable are attached. The aerostat is launched by disconnecting it from the mooring cradle and paying out the cable from the main winch. Once the aerostat is on station it operates automatically. Electrical power (if required) is provided through conductors in the tether cable by the same gas driven generator that provides power to the tether winch. Flight parameters such as the pitch angle, pressure, cable angle, etc. are displayed on a panel in the launch truck so



Sheldahl

FIGURE 4

Aerostat System
Configuration

control can be maintained in the event of a malfunction or change in weather conditions.

3.2.3.1.2 Powered Aerostat

It is anticipated that the powered aerostat can be prepared for launching in a similar manner as the tethered version. However, provisions must be made for attaching the engine, support equipment and payload. Upon completion, the aerostat would be launched and recovered by means of trailing handling lines. These lines are staked down during inflation of the aerostat and would be rapidly released after engine start-up. For recovery the aerostat would match speeds with the prevailing winds in the recovery area to allow the lines to be grasped and secured. A small ground station will provide operational control of the powered aerostat during relay missions.

3.2.3.2 Aerostat Relocation

Relocation of the aerostat can be accomplished by towing it by its tether either with the launch vehicle or by a helicopter. The desirable features of relocation by the launch vehicle are the elimination of assembly and disassembly time between moves, reduction in the size of the launch crew, less inflatant required, and an increase in on-station operating time. Transfer operations are contingent upon local terrain, vegetation, available roads/ trails and wind loading on the aerostat.

The helicopter transfer technique is accomplished by attaching the tether to a large weight (approximately 50% heavier than the free lift of the aerostat). The helicopter would then provide the additional lift and forward force necessary to transfer the "dummy" weight and aerostat to the new location (see Figure 5). This technique has been successfully tested at speeds up to 70 knots. This method provides the system with a rapid site transfer resulting in a reduction of operating time loss, less ground support equipment required, reduced set-up time and increased flexibility in site selection.

During operation Fat Cat, conducted by the Air Force at Cape Kennedy in 1972, an aerostat (200,000 ft^3) reached a speed of 68 knots while being towed by a helicopter. In

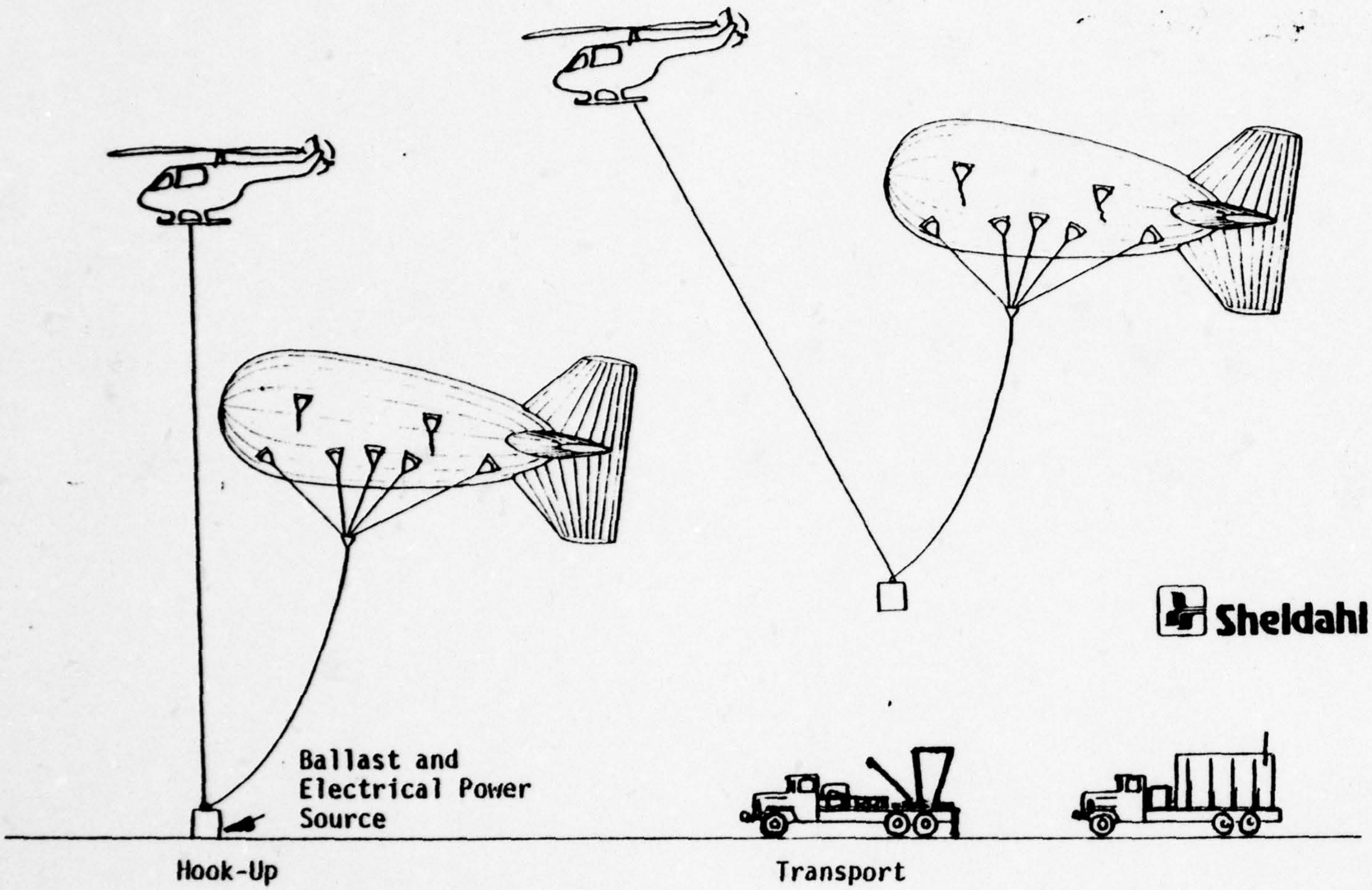


FIGURE 5

System Relocation

addition, an instrumented aerostat (750 ft^3) was moved by truck at a wide range of velocities and pitch angles without any related stability problems.

3.2.3.3 Buoyant Gas Characteristics

Many gases are available to provide buoyancy to aerostats including hydrogen, helium, coal gas, hot air and ammonia. Hydrogen provides 8% more lift than helium and can be generated at the launch site (there currently exist several types of hydrogen gas generators used by the meteorological sections of artillery batallions and Air Force weather teams that can be utilized to manufacture the required gas). However, hydrogen's explosive flammability creates severe safety and survivability problems. Coal gas shares hydrogen's flammability and, along with ammonia provides less buoyancy than helium. Hot air provides the least buoyancy and has the additional disadvantage of requiring continual consumption of fuel to maintain lift during extended endurance missions. Considering these factors helium was chosen as the buoyant gas to be used in this analysis.

Helium is available commercially in cylinders containing 285 cubic feet of gas that weigh 115 lbs each and measure 8 inches in diameter by 4.5 feet in height. In addition, cyclinders can be purchased in 12 tank banks with a 3,420 cubic foot capacity. It is anticipated that the required helium will be transported on trailers as part of the aerostat launch group. Special helium tank configurations would be designed to meet the requirements of the particular aerostat system being deployed.

3.2.3.4 Environmental Considerations

A number of environmental parameters can influence the deployment of aerostat systems including lightning, rainfall, snow, wind speed and atmospheric conditons.

Lightning in particular can be a severe threat to a tethered aerostat system. This threat is amplified further if the payload requires the transmission of electrical power by hard wire from a ground power source. In addition, airborne electrical components associated with the payload may be damaged by lightning strikes. A system would have to be designed to eliminate or minimize the hazard of lightning strikes. This design can be characterized by a conducting

cable, faraday cage protection for the aerostat/winch and adequate grounding.

During periods of heavy rainfall or moderate to heavy snow fall, the operational altitude of an aerostat system may be reduced. However, this type of weather condition will also reduce the operational capability of other platforms, such as aircraft and remotely piloted vehicles (RPV's).

High wind conditions can have an adverse effect on aerostat systems. Powered aerostats would be of limited use in high winds since the maximum realistic airspeed capability is around 40 knots, wind speed in excess of 20 knots would impair operations by doubling the travel time into the wind. Tethered aerostats can be operated at wind velocities up to 70 knots.

The aerostat system is designed for the ambient atmospheric conditions and mission altitudes at which it is to be flown. Due to variations in atmospheric temperature, solar heating effects occurring during a mission and altitude, a ballonet or dilation panel must be included in the balloon structure to permit expansion and contraction of the helium. A variation of 40°F in the ambient temperature would cause the aerostat volume to expand 8 percent. Similar helium density variations can be produced by solar heating; that would result in an increase in buoyancy. This would have to be compensated for aerodynamically in a powered aerostat configuration. Significant variations in aerostat lift might limit the minimum airspeed or require the venting of helium.

3.2.3.5 Detectability

Detection of aerostat systems can theoretically be achieved by optical radar, infra-red and acoustical techniques. Tethered vehicles are not as detectable by infra-red devices as are powered aerostats and are virtually undetectable by acoustic devices. Again, we are assuming that the aerostat systems are not penetrating enemy airspace and operate approximately 15-30 KM behind the FEBA.

Detection of the aerostat by optical means is possible, however, the use of camouflage colors would make detection difficult. In addition, it appears that detection

of an airborne aerostat is more difficult than might be intuitively assumed.

The major radar reflectant components of powered aerostats are,the payload, avionics and engine. The aerostat envelope provides little or no radar return. A powered system flying a stand-off mission will have a low probability of detection by MTI radars since its velocity is primarily tangential to the radar and the rotating propeller can be shielded. A tethered aerostat would be even more difficult to detect since the only motion is associated with wind changes. An aerostat system probably would not be detected by a radar operating in an MTI mode. In addition, even when a radar does not employ the MTI mode, a tethered aerostat would be difficult to detect since it would appear near the horizon for a radar looking across the FEBA. While use of a conducting tether would provide a radar return, it should be difficult to separate this return from the background clutter.

Emission levels of aerostat systems should be too low to be effectively engaged by IR seeking weapons. This is dependent upon sunlight reflected and the size of aerostat.

3.2.3.6 Vulnerability

The potential threat to aerostat systems is dependent upon the concept of operation and weapons employed. Under the employment concept being considered in this analysis the airborne platform would operate approximately 15 - 30 KM behind the FEBA. At this position aerostat systems would be vulnerable to surface-to-air missiles (SAMs) and aircraft delivered weapons. Anti-aircraft guns generally do not have a sufficient range to pose a threat to non-penetrating systems. In addition, there is a potential danger of artillery assault on the components of the ground control system associated with the type of airborne platform concept.

The following potential threats to the system will be addressed below:

(a) Surface-to-Air Missiles
(b) Anti-Aircraft Guns
(c) Air-to-Air Missiles
(d) Air-to-Air Cannon Fire
(e) Artillery Fire

Surface-to-Air Missile (SAM)

The effectiveness of the SAM's will be considered only from a detection and target firing opportunity viewpoint, since the vulnerability of the aerostat to detonation of a SAM is assumed. As indicated in the section on Detectability, SAMs will encounter difficulty in identifying and locking on to a tethered aerostat with their radar. Some types of SAMs whose radar operate on the Doppler Effect (SA-6) will be unable to fire at a stationary target. For a powered aerostat the balloon envelope would provide little or no radar return. The major radar reflectant components are the payload, avionics and engine that provide a return similar to a small RPV. In addition, on a cost effectiveness basis, the use of SAMs is probably not too likely unless the system is carrying a payload that would merit a response using a sophisticated missile.

Anti-Aircraft Guns

If aerostat systems are operating 15-30 KM on the friendly side of the FEBA it is not likely that they will be vulnerable to enemy anti-aircraft weapons. This area of operation is beyond the effective range of all but the largest anti-aircraft guns. Further, target acquisition by these weapons is conducted by radar and visual contact and would be subject to the limitations already noted.

Air-to-Air Missiles

Missiles of this type are either heat seeking or radar guided. The heat seeking missile cannot be used effectively because the aerostat systems are not a source of sufficient IR radiation. For radar-guided missiles the radar cross section of the aerostat and its payload is too small to lock on. Since the tethered aerostat is a stationary target at a relatively low altitude the airborne radars are quite ineffective in identifying the target. Powered aerostat systems would similarly provide a small radar cross section which is associated with the avionics propulsion system and payload.

Air-to-Air Cannon Fire

This method may prove to be more effective against the aerostat than any of the other threats mentioned. Detection of

an aerostat by an enemy pilot is possible, although this risk can be reduced through the use of camouflage. Upon identification of the target by an aircraft a close approach (few hundred yards) must be made in order to achieve effective results with cannon fire. It is assumed that the location of the tethered airborne system will be in close proximity to friendly anti-aircraft weapons that could make it difficult and costly for an enemy fighter attack.

Artillery Fire

An artillery assault on an aerostat system control complex can be quite effective. The existence of a tether (tethered system) provides an indication as to the ground station's location. To alleviate this problem support equipment could be remoted a few thousand feet from the tether tie down point. Further, to reduce the effectiveness of attacks against the aerostats, decoy aerial platforms could be provided to reduce the danger of destruction of the aerostat system and payload. Finally, the payload monitoring station can also be deployed in defiladed areas.

3.2.3.7 Survivability

An aerostat is not as susceptible to projectiles and fragmentation munitions as it may seem. Experience has shown that it is quite difficult to shoot down an aerostat. If the aerostat is hit, the helium leakage rate would be slow enough (precluding massive projectile fragmentation damage) to allow the vehicle and payload to be retrieved. Upon recovery the aerostat could be repaired in the field and flown again within a short time. Even if the vehicle is damaged beyond repair the payload can usually be recovered without damage and installed on a spare aerostat. If a sufficient number of hits are sustained by a powered aerostat system there is a possibility that the flight would be terminated without being able to return to base. In this case the vehicle would have to be located and then recovered (see Appendix A).

The following was extracted from the Jan 8, 1973 issue of Aviation Week and Space Technology: "The difficulty of shooting down a balloon was unintentionally demonstrated several years ago in South Vietnam during ARPA tests of a small, non-tethered balloon which was being used as a platform

for acoustic sensors to detect enemy ground troops. The balloon carried a small battery powered propulsion unit and bore the code name of 'Silent Joe ' ".

"When Silent Joe failed to respond properly to ground commands, and started heading for Cambodia, armed helicopters were dispatched to shoot it down lest its classified payload fall into enemy hands. Despite the best efforts of the armed helicopters, the Silent Joe balloon was last seen flying unscathed into Cambodia."

3.2.3.8 Reliability and Maintainability

3.2.3.8.1 Tethered Aerostat

This vehicle is simpler and more reliable than the powered version. No navigation, radio link, propulsion, autopilot or airborne power equipment is required. Little maintenance work is required on the aerostat except for normal helium leakage, leaks caused by a damaged envelope and breaks in the conducting tether. During normal operation the aerostat will leak a small amount of helium every day, usually 1%. This would become a problem only after extensive periods of operation. The requirement for the REMBASS repeater mission is 24 hours and the aerostats being considered in this analysis are capable of continuous operations for at least 48 hours. An unusually high leak rate would require a search for the source and patching or replacement of the aerostat. Normally replacement of an aerostat will be required after six months to one year due to ultraviolet aging of the fabric. The conducting tether has a special maintenance problem concerning the strengths and continuity of the cable. This must be checked periodically to locate and repair any breaks. If a nylon tether is utilized (for smaller aerostats) this is not required.

3.2.3.8.2 Powered Aerostat

A powered aerostat contains subsystems that are not found in the tethered version that would increase reliability and maintenance problems. In addition to the maintainability requirement associated with the aerostat envelope, the propulsion system and avionics require periodic maintenance.

3.2.3.8.3 Repeater Dependency

Both the tethered and powered aerostats are capable of supporting a payload for extended periods of time. However, for this particular application the aerostat flight time is dependent upon the operational flight time of the repeater. During project SEEK Skyhook in 1975 an aerostat supporting MTI radar operated continuously for forty hours without any mishap. Therefore maintenance on the aerostat can be conducted when the repeater batteries need replacement (24 hours) and when the unit is serviced. This will eliminate the need to maintain the aerostat apart from the repeater payloads.

3.2.4 Cost Considerations

The technology required for the development of an aerostat as a suitable REMBASS platform is essentially already available. Any additional funds necessary to complete the development of a military system (particularly in the case of a tethered aerostat) could be considered insignificant on a life cycle cost basis.

The areas of greatest expenditure for an aerostat platform alternative would be those of operation and support. Use of an aerostat as a platform for the REMBASS relay would require each division so equipped to provide an operating crew and support vehicles on a continuous basis, and occasional additional personnel during times of launch and retreival (see Table 3). The requirement for continuous crew support at each division, especially when considered over a period of up to 10 years, constitutes probably the single largest, and most significant, cost factor in the life cycle.

Further, in almost every cost area, the costs associated with a powered aerostat are greater than those of a tethered aerostat. Use of a powered aerostat would eventually require considerably greater life cycle expenditures (attributable to larger size, engines and fuel, cost of procurement and greater operating crew size) than would a tethered aerostat, and at the same time would probably fail to achieve the performance level attainable with the tethered configuration.

TETHERED AEROSTAT CHARACTERISTICS

AEROSTAT VOLUME	WEIGHT	LENGTH	DIAMETER	OPERATING ALTITUDE	TETHER WT & TYPE	MA W F OPE
10,000 cuft	265 lbs	59 ft	20 ft	2000 ft	30 lbs/1000 ft (conducting)	70
7,000 cuft	210 lbs	45 ft	17 ft	2000 ft	30 lbs/1000 ft (conducting)	70
2500 cuft	76 lbs	35 ft	13 ft	2000 ft	11 lbs/1000 ft (nylon-non conducting)	40

NOTE: THE INFORMATION PROVIDED ABOVE IS OFFERED AS A GUIDE
CHARACTERISTICS OF TETHERED AEROSTAT CONFIGURATIONS
POSSIBLY SUPPORT A REMBASS REPEATER

TABLE 2

TETHERED AEROSTAT CHARACTERISTICS

DIAMETER	OPERATING ALTITUDE	TETHER WT & TYPE	MAXIMUM WIND FOR OPERATIONS	APPROX. PAYLOAD WT.	BALLONET BLOWER REQUIRED	MANUFACTURER
0 ft	2000 ft	30 lbs/1000 ft (conducting)	70 Knots	43 lbs.	Yes	Sheldahl
7 ft	2000 ft	30 lbs/1000 ft (conducting)	70 Knots	30 lbs.	Yes	Sheldahl
3 ft	2000 ft	11 lbs/1000 ft (nylon-non conducting)	40 Knots	5-20 lbs.	No	Raven

E INFORMATION PROVIDED ABOVE IS OFFERED AS A GUIDE DESCRIBING THE ARACTERISTICS OF TETHERED AEROSTAT CONFIGURATIONS THAT CAN SSIBLY SUPPORT A REMBASS REPEATER

TABLE 2

AERIAL PLATFORM	PAYLOAD CAPABILITY (1)	NUMBER OF PLATFORMS REQUIRED (2)	LOITER TIME OF PLATFORM (3)	VULNERABILITY (4)
Tethered Aerostat	All repeater alternatives are supportable.	One platform	From 2 days to 1 week	Aircraft delivered weapons Artillery assault
Powered Aerostat	All repeater alternatives are supportable	One platform	Depends on fuel capacity	SAM's and aircraft delivered weapons

TABLE 3

TETHERED VERSUS POWERED AEROSTAT COMPARISON

ER ORMS D	LOITER TIME OF PLATFORM (3)	VULNERABILITY (4)	SURVIVABILITY (5)	OPERATIONAL ALTITUDE (6)	REUS- ABILITY OF PLATFORM (7)
form	From 2 days to 1 week	Aircraft deliver- ed weapons Artillery assault	Can withstand some projectile damage. Cannot be jammed by EW.	2000 ft	Can be re- used for at least one year.
form	Depends on fuel capa- city	SAM's and air- craft delivered weapons	Can withstand some projectile damage. RF link can be jammed by EW.	2000 ft	Can be operated for at least one year.

TABLE 3

TETHERED VERSUS POWERED AEROSTAT

COMPARISON

AERIAL PLATFORM	SET UP/TEAR DOWN REQUIREMENTS (8)	SUPPORT (9)	RELIABILITY (10)	CONSIDERATIONS (11)	TECHNICAL RISK CONSIDERSATI (12)
Tethered Aerostat	One hour for each	Set up by 8 men, operated by 2 (depends on size of aerostat) 2 2½ Ton trucks 2 helium trailers	High	Designs exist or can be developed	Low
Powered Aerostat	1½ hours for each	8-10 men, 2 2½ Ton trucks 2 helium trailers	High	Designs must be developed	Low

TABLE 3

CONTINUED

	RELIABILITY (10)	CONSIDERATIONS (11)	TECHNICAL RISK CONSIDERSATIONS (12)	PHYSICAL CHARACTERISTICS (13)	AREA OF OPERATION (14)
n, tat) ks 1-	High	Designs exist or can be developed	Low	Depends on size of payload (See Table 2)	15-30 Km behind FEBA
1 2 1-	High	Designs must be developed	Low	Depends on size of payload, an additional 71 lbs must be supported. This represents the avionics and propulsion system of the aerostat.	15-30 Km behind FEBA

TABLE 3

CONTINUED

RT	RELIABILITY (10)	CONSIDERATIONS (11)	TECHNICAL RISK CONSIDERSATIONS (12)	PHYSICAL CHARACTERISTICS (13)	AREA OF OPERATION (14)
8 men, y 2 n rostat) rucks rail-	High	Designs exist or can be developed	Low	Depends on size of payload (See Table 2)	15-30 Km behind FEBA
2 2½ ks 2 rail-	High	Designs must be developed	Low	Depends on size of payload, an additional 71 lbs must be supported. This represents the avionics and propulsion system of the aerostat.	15-30 Km behind FEBA

TABLE 3

CONTINUED

AERIAL PLATFORM	DEDICATED/ NON-DEDICATED SYSTEM (15)	ENVIRONMENTAL METEOROLOGICAL CONSIDERATIONS (16)
Tethered Aerostat	Dedicated	Can operate in high winds. Lightning presents problem to conducting tether Heavy snow fall can terminate mission
Powered Aerostat	Dedicated	Operation affected by high winds. Heavy snowfall can terminate mission.

TABLE 3

CONTINUED

CHARACTERISTIC	TETHERED AEROSTAT ADVANTAGES	 DISADVANTAGES	 A
(1) Launch and Recovery	(a) Easily launched and recovered without auxiliary equipment. (b) Can be accomplished under severe wind conditions. (c) Can be transported to new site without need to deflate.	Number of personnel required for launch is dependent upon size of aerostat (can be as many as 8).	C n o a t
(2) Flight Operations	(a) Long mission duration. (b) Can operate in high winds (70 knots). (c) Requires minimum number of personnel to operate. (d) All weather capability (excluding heavy snowfall) (e) Does not have problems associated with propulsion system, fuel, noise, etc.	* (a) Lighting presents problem to tether, if conducting. (b) Accumulation of snow on aerostat can produce mission termination.	(m t v (o

* Smaller Aerostats can
with nylon tether.

TETHERED AEROSTAT		POWERED AEROSTAT	
ES	DISADVANTAGES	ADVANTAGES	DISADVANTAGES
ily launched vered without y equipment. be accompli- er severe ditions. be trans- o new site need to	Number of personnel required for launch is dependent upon size of aerostat (can be as many as 8).	Can be flown to new site depending on wind conditions and fuel consump- tion.	(a) Due to propulsion system launch and recovery is more complicated. (b) Aerostat cannot be launched and recover ed under severe wind conditions. (c) Launch and recovery operations require more person- nel.
g mission . operate winds (70 uires mini- er of person- perate. weather capa- excluding owfall) s not have associated pulsion fuel, noise,	* (a) Lighting presents problem to tether, if conducting. (b) Accumulation of snow on aerostat can produce mission termination.	(a) Aerostat is more responsive then tethered version. (b) Larger area of coverage.	(a) Aerostat must be larger to support increased payload (propulsion system, avionics, etc.) (b) Operations are adversely affected by high winds.

* Smaller Aerostats can be operated with nylon tether.

	TETHERED AEROSTAT		
CHARACTERISTIC	ADVANTAGES	DISADVANTAGES	AD
(3) Detection	(a) Difficult to detect with MTI radar (no motion) (b) Difficult to detect near the horizon by radar looking across the FEBA. (c) Conducting tether would be difficult to locate due to clutter producing background. (d) Aerostat envelope provides little or no return.	Visual detection may be accomplished at very close ranges.	Lo de op mo sp is ta
(4) Vulnerability	Anti-aircraft weapons do not pose threat.	(a) Under the employment concept discussed in this analysis the aerostat would be vulnerable to aircraft delivered weapons. (b) Support vehicles are vulnerable to artillery assault.	Su no ae

TABLE 4

(Continued)

TETHERED AEROSTAT		POWERED AEROSTAT	
S	DISADVANTAGES	ADVANTAGES	DISADVANTAGES
icult to th MTI motion) icult to ar the y radar cross the ucting uld be to locate utter back- stat provides no return.	Visual detection may be accomplished at very close ranges.	Low probability detection by radar operating in MTI mode due to slow speed and velocity is primarily tangential to radar	(a) Larger size due to added weight of avionic & propulsion system better visual detection (b) Readily detected by IR equipment.
raft o not at.	(a) Under the employment concept discussed in this analysis the aerostat would be vulnerable to aircraft delivered weapons. (b) Support vehicles are vulnerable to artillery assault.	Support vehicles not located by aerostat tether.	Vulnerable to SAM's and aircraft delivered weapons.

TABLE 4

(Continued)

2

CHARACTERISTIC	TETHERED AEROSTAT ADVANTAGES	TETHERED AEROSTAT DISADVANTAGES	ADVANT
(5) Survivability	(a) If aerostat is hit, the helium leakage rate would be slow enough (precluding massive projectile fragmentation damage) to allow the vehicle and payload to be retrieved. (b) Cannot be jammed by EW methods (no RF link required)	Massive fragmentation damage will destroy the aerostat	Can op minor caused iles.
(6) Logistics	Fuel is not required	Acquisition and transportation of helium.	

TABLE 4

(Continued)

ERED AEROSTAT		POWERED AEROSTAT	
	DISADVANTAGES	ADVANTAGES	DISADVANTAGES
at is um would h assive ag- age) to icle o be e F)	Massive fragmentation damage will destroy the aerostat	Can operate with minor damage caused by projectiles.	(a) A sufficient number of hits could terminate a mission without the aerostat being able to return to base. (b) RF data link can be jammed. (c) Massive fragmentation damage will destroy the aerostat.
e-	Acquisition and transportation of helium.		(a) Must provide fuel (b) Must provide for helium

TABLE 4

(Continued)

CHARACTERISTIC	TETHERED AEROSTAT ADVANTAGES	TETHERED AEROSTAT DISADVANTAGES	ADVAN
(7) Maintainability and Reliability	No navigation radio links, propulsion, autopilot or airbase power equipment required.	(a) Normal helium leaks. (b) Leaks caused by tears in the envelope. (c) Electrical continuity of tether if conducting tether utilized.	
(8) Cost	Less complex and therefore less expensive to employ.		

TABLE 4

(Continued)

HERED AEROSTAT		POWERED AEROSTAT	
	DISADVANTAGES	ADVANTAGES	DISADVANTAGES
radio sion, airbase nt	(a) Normal helium leaks. (b) Leaks caused by tears in the envelope. (c) Electrical continuity of tether if conducting tether utilized.		(a) Must maintain avionics and propulsion systems. (b) Decreased reliability due to increased number of subsystems. (c) Normal helium leaks. (d) Leaks caused by tears in the envelope.
and there- ensive			More complex and costly.

TABLE 4

(Continued)

3.2.5 Conclusion

Based on the information developed in this section it was determined that the tethered aerostat will provide a stable and relatively inexpensive platform for the REMBASS repeater. The powered aerostats operational capability is limited by support requirements, environmental considerations, maintainability/reliability considersations, logistics, vulnerability/survivability and cost. This information is summarized in Tables 2 and 3 which provide a comprehensive comparison of the characteristics and operational parameters associated with each type of aerostat. In addition, Table 4 lists the advantages and disadvantages associated with each type of system.

3.3 Remotely Piloted Vehicles (RPVs)

A number of Mini Remotely Piloted Vehicles (RPVs) in various stages of design and development are currently available. This section of the analysis will address the concept as associated with the airborne platform mission. In particular, the proposed Army Mini RPV effort will be addressed. It should be noted that only a cross section of the available RPV systems were considered in this analysis, however, they represent the current state of the art in RPV concepts that are being proposed. As before, a matrix has been prepared outlining the Mini RPV characteristics and its ability to support the proposed repeater alternatives. The disadvantages and advantages associated with the Mini RPV concept have also been provided.

3.3.1 Introduction

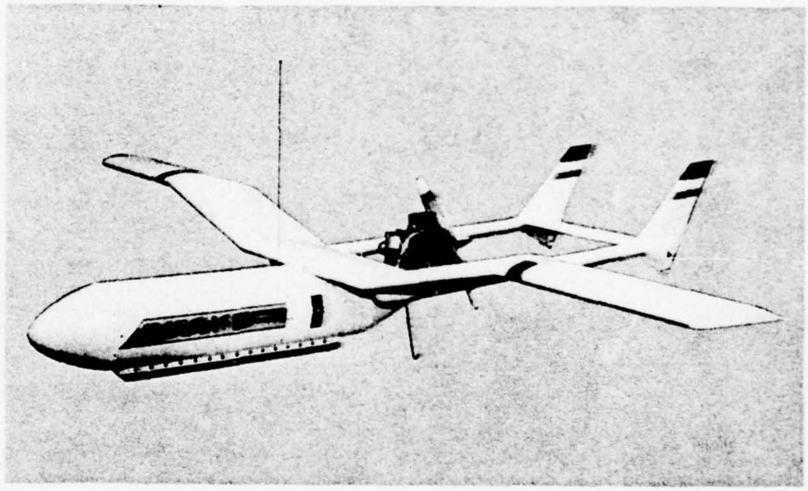
The Mini RPV system is comprised of an air vehicle, ground control station (GCS) and launch/recovery/support equipment. The RPV is a small fixed wing air vehicle supporting the mission payload and controlled by the GCS. Launching is accomplished by accelerating the vehicle into the air utilizing a catapult or the RPV's own power, Upon completion of the mission, the aircraft is retrieved by the recovery system. A number of systems are being considered including retrieval net, steerable/non-steerable parachute and belly skids attached to the airframe.

E-SYSTEMS INC.
Melpar Division

Technical Data Sheet

REMOTELY PILOTED VEHICLE E-100X

A ONE-HUNDRED-POUND EXPERIMENTAL RPV DESIGNED FOR A VARIETY OF MISSIONS



POTENTIAL MISSIONS:

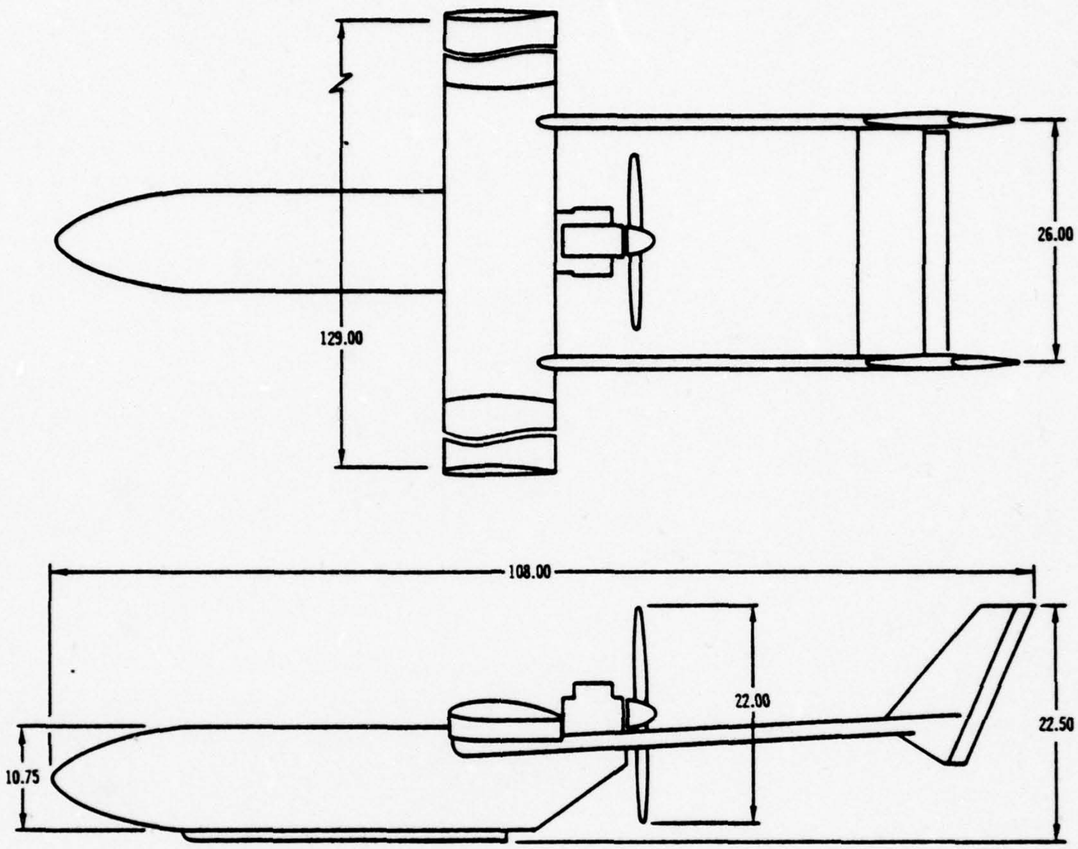
- TELEVISION RECONNAISSANCE
- JAMMING
- COMMUNICATIONS RELAY
- TACTICAL MISSION STRIKE SUPPORT
- REMOTE COMMUNICATIONS INTERCEPT
- PHOTOGRAPHIC RECONNAISSANCE

The E-100X Remotely Piloted Vehicle is the third in a series of miniature airborne payload platforms. This one-hundred-pound experimental RPV was designed and built under IR&D to anticipate the need for larger payload carrying capabilities.

The basic aircraft is divided into three major assemblies: Pod, Wing Assembly, and Booms and Tail Assembly. The major assemblies are configured for rapid assembly and disassembly for ease of handling. The Pod section is an RFI sealed unit which houses the onboard electronics packages. The Wing Assembly contains a sealed fuel tank. The propulsion system is a 4-cylinder, 9-horsepower Rosspower Engine. Engine RFI and vibration have been virtually eliminated by unique shielding and isolation methods.

Design and operational considerations are aimed at the professional user while maintaining low cost with mission flexibility. The flight control system provides the pilot with manual real time or full autopilot control options. Air-to-ground telemetry is available for monitoring flight progress and navigation calculations.

The E-100X RPV offers the user considerable latitude in the payload to be carried and the mission profile that can be selected. Some 3 cubic feet of volume and greater than 50 pounds of weight are available for payload considerations. A miniature low-cost Television Reconnaissance System has been designed and is available as a payload.



AIRCRAFT SPECIFICATIONS – TYPICAL		AIRCRAFT PERFORMANCE – TYPICAL	
DESIGN GROSS WEIGHT	100 lb	PAYLOAD WEIGHT	50 – 55 lb
WING SPAN	129.0 in.	RATE OF CLIMB	1000 fpm at SL
WING AREA	2064.0 sq in.	CRUISE VELOCITY	75 knots
AIR FOIL	NACA 4415	MAXIMUM VELOCITY	95 knots
OVERALL LENGTH	108.0 in.	STALL VELOCITY	42 knots
OVERALL HEIGHT	22.5 in	CEILING	Above 10,000 ft MSL
ENGINE	Rosspower 4 cyl, 2 stroke, 9 h.p. at 8000 rpm	ENDURANCE	5 hrs plus
PROPELLER	2 blade, fixed 12 in. pitch, 22 in. diameter	LAUNCH	Vehicle top or catapult
FUEL CAPACITY	18 lb (approximately 3 gallons)		

FIGURE 6

E-SYSTEMS INC.
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REMOTELY PILOTED VEHICLE E-100X

GENERAL ARRANGEMENT, MINI-MULTI-PURPOSE RPV

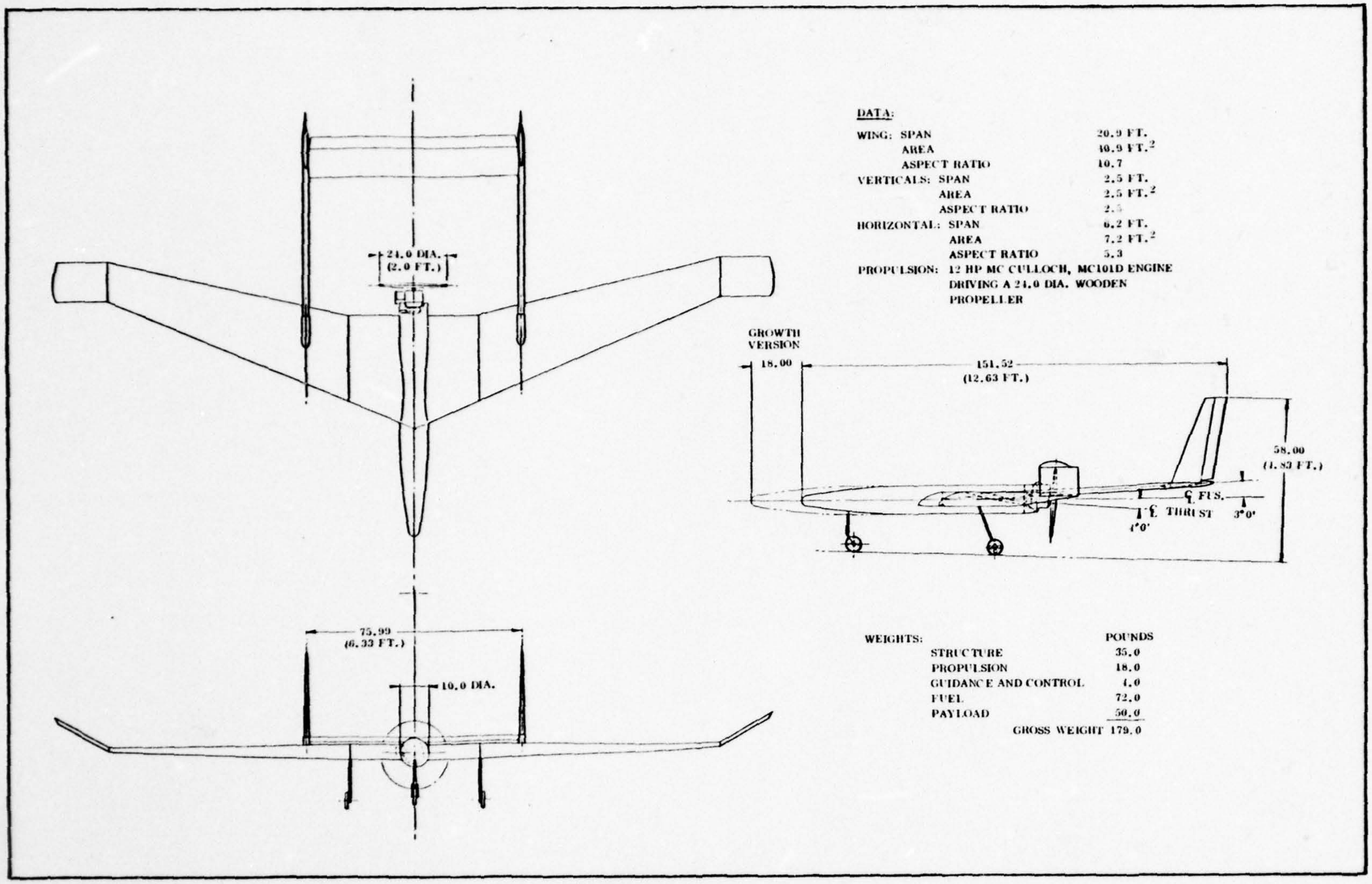

FIGURE 7
TELEDYNE RYAN AERONAUTICAL
"MINI SNIFFER"

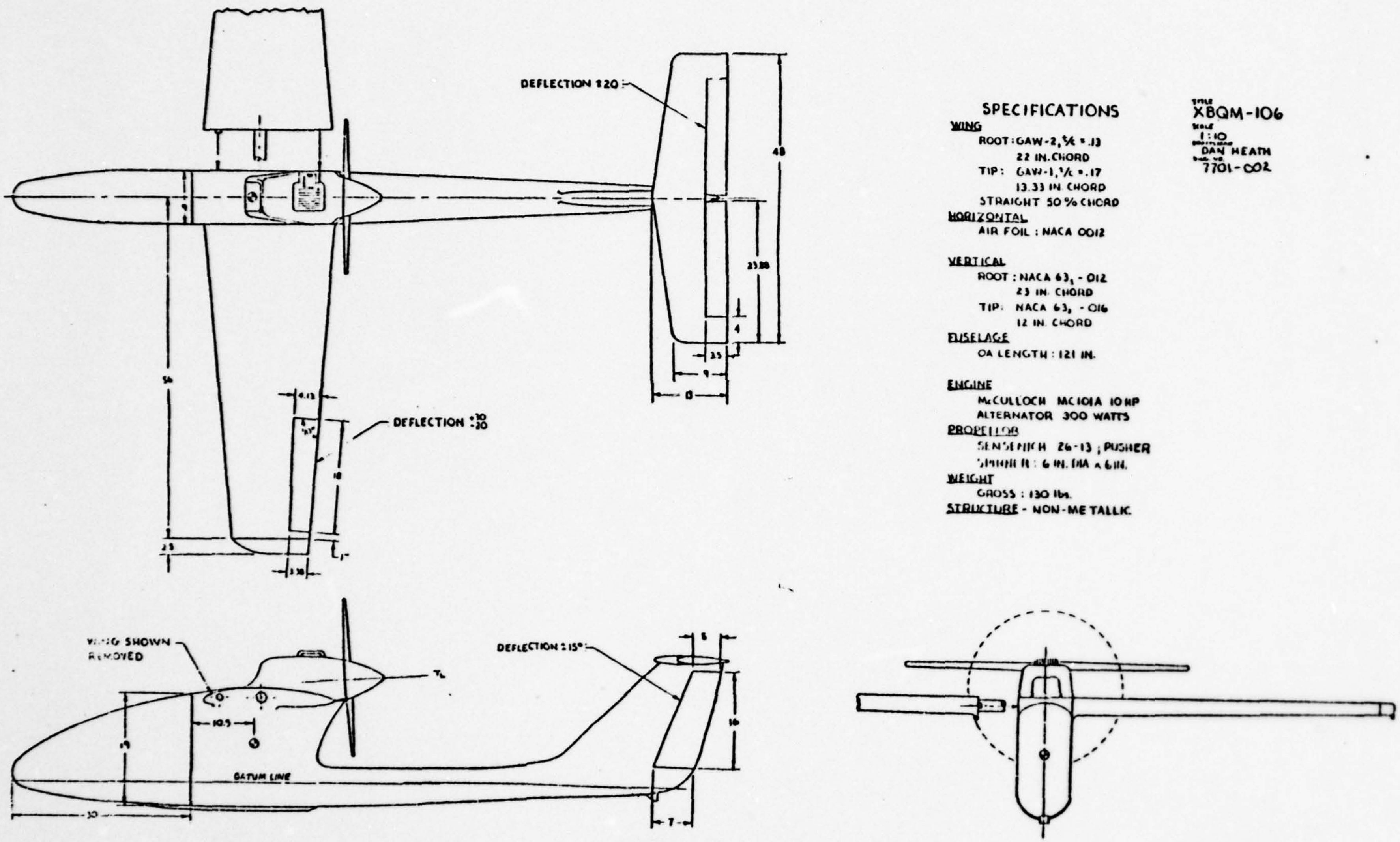

FIGURE 8

AIR FORCE XBQM-106
MINI-RPV TECHNOLOGY
DEMONSTRATOR

3.3.2 Mini RPV Description

The information provided below describes the parameters associated with the various Mini RPVs currently being developed. A particular type of RPV has not been addressed in the table below, rather a cross section of the characteristics of the various RPVs is provided (three different RPV concepts are shown in Figures 6,7 and 8).

MINI RPV CHARACTERISTICS

Gross Weight:	21 - 225 lbs
Wing Span:	6 - 22 ft
Length:	5 - 10 ft
Payload:	10 - 60 lbs
Maximum Speed	90 - 200 Knots
Minimum Speed:	30 - 60 Knots
Cruise Speed:	45 - 115 Knots
Endurance:	1 - 24 hours.
Ceiling:	10,000 + ft MSL
Launch:	Truck Top, Catapult, JATO
Recovery:	Net, Aircraft Skid, Parachute
Autopilot:	Combination of manual and preprogrammed flight operations

As can be seen the various concepts under development incorporate a significant degree of variation (see Table 5).

Rather than addressing each concept individually, we will generally concern ourselves with the Army's most likely candidate. Consequently, in addition to the information given above, the characteristics of the proposed Army Mini RPV concept as obtained from the US Army Aviation Research and Development Command are provided. It is anticipated that this platform will be available for use by REMBASS in the 1980 time frame if so desired.

Gross Weight:	Shall not exceed 220 lbs.
Wing Span	12 ft.
Length:	6 ft.
Payload:	51 lbs.
Maximum Speed:	Classified
Minimum Speed:	Classified
Cruise Speed:	Classified
Endurance:	3 hrs.
Ceiling:	12,000 ft MSL
Launch:	Catapult
Recovery:	Net or parachute
Autopilot:	Combination of manual and preprogrammed operation

RPV TYPE	MANUFACTUER	GROSS WT (LB)	WING SPAN (FT)	LENGTH (FT)	PAYLOAD WT (LB)	MAX SPEED (KTS)	MIN SPEED (KTS)	CRUISE SPEED (KTS)
Aquila Test Bed		170	12	6	50	90	37	49-65
Proposed Army Mini RPV Concept		Max 220	12	6	51	Classified	Classified	Classified
E-100X	E-Systems Melpar	100	10.75	9	50-55	95	42	75
E-45	"	45	7.9	7.8	15	-	34.8	43.4
E-75 (Modified)	"	120	10	7	25	100	-	-
Mini-Sniffer Concept	Teledyne Ryan	222	21.12	14.0	60	-	-	45-58
XBQM-106 (6 Mods)	Air Force Technology Demonstrator	90-180	9-14	10	25-80	200	50	75-100

MINI RPV CONCEPTS

TABLE 5

ENGTH (FT)	PAYLOAD WT (LB)	MAX SPEED (KTS)	MIN SPEED (KTS)	CRUISE SPEED (KTS)	ENDURANCE (HRS)	CEILING (FT)	LAUNCH & RECOVERY METHODS	AUTOPILOT
6	50	90	37	49-65	3	12,000 MSL	Catapult launch, net, recovery	Combinatio of manual and preprogrammed operation
6	51	Classified	Classified	Classified	3	12,000 MSL	Catapult launc[illegible] net [illegible] parachute recovery	"
9	50-55	95	42	75	5+	10,000 MSL	Launch: Vehicle top or catapult Recovery: Runway	"
7.8	15	-	34.8	43.4	5	10,000 MSL	"	"
7	25	100	-	-	10	10,000 AGL	"	"
4.0	60	-	-	45-58	24	to 20,000	Runway	"
10	25-80	200	50	75-100	6	10,000 MSL	Catapult, dolly or JATO Recovery: belly skid onto smooth surface	"

MINI RPV CONCEPTS

TABLE 5

3.3.3 Operational Considerations

3.3.3.1 Concept of Operation

It is anticipated that the Mini RPV system would be dedicated to the repeater mission. Payload limitations, operational requirements and area of operation would all tend to limit the RPV to the REMBASS mission.

Under the organizational concept proposed in the draft ROC for a Remotely Piloted Vehicle (RPV) Target Acquisition/Designation Reconnaissance System (TADRS), USATRADOC ACN 22637, an operational section consisting of 13 personnel would operate the RPV system. The section would be equipped with a ground control station, launcher and recovery equipment, assembly/maintenance shelter, aircraft with repeaters, and associated ground support equipment.

Present plans allow for a dead reckoning mode of operation (navigation without commands from the ground control station) for a limited amount of time. It is possible that future aircraft would be capable of staying in a loiter pattern for the entire REMBASS relay mission without commands from the GCS until recovery time. Under the present concept recovery and launch of the aircraft will be controlled by an operator in the GCS.

3.3.3.2 Payload Capability

The ability of a Mini RPV to carry the designated repeater payload would vary as a function of the vehicle size, weight and available electrical power. As previously indicated there are a number of repeater alternatives under consideration ranging in weight and volume from 3 lbs. to 40 lbs. and 9 cubic inches to 1300 cubic inches respectively. Of the many Mini RPVs presently available, any number of them could be configured to handle the variety of repeater alternatives presented. Electrical power can be supplied by either the aircraft or batteries. The proposed Army Mini RPV concept will support a payload weight of 51 lbs., this is sufficient to handle the largest repeater alternative being considered.

3.3.3.3 Endurance

The loiter time, or endurance, of a Mini RPV platform

is a function of the design of the aircraft. Recent developmental efforts have produced aircraft that can remain aloft for over 24 hours. In addition, endurance capabilities of from 30 to 40 hours have been technologically proven and are feasible for low speed, propeller driven configurations.

Under the present Army concept, at least two airborne platforms would be required for a 24 hour mission. The endurance for this air vehicle is three hours (although subsequent modififed versions could have a substantially greater endurance) and the second platform would be required to relieve the first RPV. This estimate does not include the spares requirements that would drive the inventory to a larger number. It should also be noted that the first generation Mini RPV will not have a night capability. Future generations may be modified to incorporate night capabilities.

3.3.3.4 Environmental Considerations

Operation of the Mini RPV would be restricted under severe weather conditions, such as winds in excess of 25 knots, heavy snowfall, hail and heavy rain. In addition, the proposed Army Mini RPV will be capable of launch, flight and recovery under surface wind conditions of no more than 20 knots.

3.3.3.5 Set Up/Tear Down Requirements

The set-up time is defined as the time required by an RPV section to reach an operational status and place a repeater platform in the air from the transportation configuration. Set-up time includes the summation of all task times required to emplace the detachment resources in operable condition at the site location, launch an RPV and be prepared to recover it. The draft ROC states a requirement of one hour for set-up time. However, it is estimated that a 35-minute set-up time is capable of being achieved. This would include deployment from the transportation configuration to launch with a recovery capability.

The tear down time is defined as the time required to go from a deployed configuration to the transportation mode for movement to the next site. It is assumed that an RPV would be located on the launch but without an

airborne RPV. Under the present Army concept the tear down time requirement is 30 minutes. Again, it is anticipated that this figure can be reduced to 15 minutes.

3.3.3.6 Launch and Recovery

There are two methods presently being considered for launching the Mini RPV. Both have been tested and involve launch by catapult or by a moving vehicle.

The catapult method requires the use of a pyrotechnic, inertia or pneumatically accelerated carriage on a 15-20 foot guide rail. The carriage interfaces with the RPV fuselage and catapults the aircraft into the air.

The second method also utilizes a carriage and guide rail. However, in this case the aircraft is launched from a moving vehicle and not a stationary launcher. A mechanism releases the aircraft from the carriage when the required airspeed is achieved and it rises into the air. This method allows launching from unimproved airfields/roads, with quartering winds and a minimum of pilot skill.

The Mini RPV can either be recovered by landing the aircraft on a cleared runway/road (aircraft skids act as landing devices), utilization of a net recovery system, or by parachute. Recovery of the aircraft utilizing a runway/road (approximately 1000') involves setting the aircraft down on its skids and letting it slide to a complete halt. However, this method may result in the RPV propeller being sheared during the landing, creating a replacement problem.

The net recovery system allows the aircraft to be captured without damage. The system can be erected by two men anywhere the aircraft has approach clearance. This operation is conducted by flying the aircraft into the net and allowing it to collapse around the RPV.

To retrieve the Mini RPV by parachute it will be necessary to maneuver the aircraft over the recovery site for deployment of the parachute. This system can be employed as a full recovery system or as a backup system.

The RPV currently being proposed by the Army will utilize the net recovery or parachute system. A backup parachute recovery is also under consideration.

3.3.3.7 Detectability

Detection of the Mini RPV can theoretically be accomplished by optical methods, radar, infra-red and acoustical techniques. However, these techniques are of limited value considering the size and operational characteristics of the Mini RPV.

Detection of the Mini RPV by optical means is possible but unlikely because of its small size and operational altitude of 2000 ft. In addition, the REMBASS mission would be conducted on the friendly side of the FEBA where visual observation by the enemy is limited.

Radar detection of the aircraft is a function of its reflectant components and the size of the airframe. Since the Mini RPV is such a small size it would be difficult for an enemy radar to track and lock on to the aircraft. It should also be noted that it is probably unlikely that an enemy radar system would be employed to track the REMBASS Mini RPV. The cost effectiveness of tracking the vehicle must be considered by the enemy in relation to exposing the radar system to identification and possible attack.

Infra-red (IR) emission levels from a Mini RPV are too low to be effectively engaged by IR seeking weapons. Again, it is probably unlikely that the aircraft would be engaged by a sophisticated weapon system.

Acoustic detection of the Mini RPV can possibly be obtained because of the acoustic noise levels of its associated engine. However, techniques exist that can substantially reduce engine noise levels and acoustic detection probability.

3.3.3.8 Vulnerability

Under the mission concept being considered in this analysis the Mini RPV would operate approximately 15-30 KM behind the FEBA. An RPV operating in this mode would be vulnerable to surface to air missiles (SAMs) and aircraft delivered weapons. Anti-aircraft guns do not have a sufficient range to pose a significant threat to non-penetrating systems.

The effectiveness of the SAMs is considered from a detection and target firing opportunity viewpoint, since the vulnerability of the RPV to detonation of a SAM is assured. Since the Mini RPV has a very small radar cross section it would be difficult for a radar tracking and fire control system to lock on to the aircraft. While it is possible that an attempt could be made to destroy the aircraft it would not be cost effective unless the payload merits a response by a sophisticated missile.

In the same light it is also unlikely that an adversary would attempt to destroy the Mini RPV with a manned aircraft. Upon entering friendly airspace an enemy aircraft would be exposed to a variety of anti-aircraft weaponry.

3.3.3.9 Survivability

Considering the proposed area of operation and the relatively small size of the Mini RPV, it would be a very difficult target to track and attack. However, if the aircraft is engaged, the components, including the airframe, propulsion system, and navigation equipment, of the Mini RPV are very susceptible to the attacking damage mechanisms. Therefore, one can conclude that if a Mini RPV is struck it would probably not be able to complete the mission.

3.3.3.10 Reliability

The probability that the Mini RPV repeater platform will perform its mission is a function of the reliability of the entire system. With respect to the aircraft, reliability is a function of the command/navigation system, radio links, propulsion equipment and recovery/launching equipment. The flight reliability is defined as the probability of the Mini RPV system, minus the mission payload, functioning so that the flight can be conducted (launch through recovery) without malfunction or failure of applicable equipment resulting in the loss of the air vehicle. Considering the number of subsystems that must operate from the air vehicle standpoint, a selective application of high reliability and redundancy will accommodate the necessary mission reliability. Finally, with respect to the repeater as a subsystem of the entire repeater/platform system, it must perform at a reliability equivalent to the aerial platform. This will result in a

system with high mission reliability.

The current Army Mini RPV concept requires that the system, less payload, will have between .92 MAV (Minimum Acceptable Value) and .97 BOC (Best Operational Capability) probability of completing a 3 hour flight (launch through recovery) without a failure. The reliability of the repeater alternatives have not been addressed in this analysis.

3.3.3.11 Maintainability

The maintainability of the aerial platform system is affected primarily by its major subcomponents. For the Mini RPV the subcomponents include the command/navigation electronics, radio link, propulsion unit and the launch/recovery system. The maintainability requirements for this system are predicated upon the complexity of its associated subsystems and the amount of time required to repair and/or replace components.

The proposed Army Mini RPV system maintainability requirements have been prepared with respect to its subsystems for the listed maintenance categories.

	MTTR Mean Time to Repair	MAXTTR Maximum Time to Repair
Organizational	.5 hr	1 hr
Field Maintenance	2 hr	4 hr

It is anticipated that Mini RPV section personnel will be capable of isolating and correcting at least 90 percent of all subsystem failures utilizing diagnostic test equipment. The remaining subsystem failures will be correctible by field maintenance. Scheduled maintenance will be performed during non-operating hours and will not require more than an average of one hour per day.

3.3.4 Cost Considerations

It would appear safe to assume that, with the exception of minor modification, all the developmental effort necessary to field the Mini RPV has been funded. The principal cost elements that would require REMBASS funding are the procurement, operating and support costs associated with the RPV, and the GCS.

MINI RPV'S

CHARACTERISTIC	ADVANTAGES	DISADVANTAGES
(1) Launch & Recovery	System can be easily transported to new site.	(a) Requires catapult for launch and net or parachute for recovery (b) Could not be launched during severe weather and wind (20 Knots) conditions (c) Requires skilled operator
(2) Flight Operations	(a) Can be flown in different mission areas (b) Can be flown at various altitudes	(a) Requires operator and command/control system. (b) Limited by short endurance capabilities (c) Cannot be operated at night (d) Cannot operate in winds in excess of 25 knots
(3) Detectability	(a) Small size limits optical and radar detection (b) Infra-red (IR) emission levels are low	

TABLE 6

CHARACTERISTIC	ADVANTAGES	DISADVANTAGES
(4) Vulnerability	Small size reduces enemy targeting capability	(a) Vulnerability to SAMs and aircraft delivered weapons (b) RF links can be jammed by EW
(5) Survivability	Small size and area of operation results in high survivability	If struck it would not complete mission.
(6) Logistics		(a) Must supply fuel to aircraft (b) Spare parts inventory must be maintained
(7) Maintainability and Reliability		(a) Sophisticated sub-components must be maintained (b) Maintenance personnel and equipment will operate with each section (c) Reliability is a function of a number of subsystems

TABLE 6

Continued

As noted in Section 3.3.3.1, according to the draft ROC the Mini RPV would require an operational section of 13 personnel. Even allowing for simultaneous operation of RPVs associated with other missions, and RPV modification for increased endurance, the REMBASS requirement for continuous 24 hour operation must result in significant operational and support costs.

The use of a Mini RPV can be expected to cause each division operating the system to generate costs for the procurement of several small fueled aircraft (with electronic guidance equipment), for the operation of those aircraft (GCS equipment, crews and fuel), and for the support of those aircraft (spares and maintenance for the aircraft, guidance equipment, launch and recovery systems, and GCS). On the basis of total life cycle cost, these accumulated expenditures can reasonably be expected to constitute a considerable and significant amount.

3.3.5 Conclusion

The Mini RPV will provide a stable and reliable platform for the REMBASS airborne repeater. Many Mini RPV configurations in various stages of development can support the repeater alternatives considered in this analysis. As previously indicated, the Army Aviation Research and Development Command is conducting a program to develop a Mini RPV system that could support various mission payload requirements. The present schedule calls for an Engineering Development contract award in Nov 1978 and an anticipated IOC in early 1983. This proposed vehicle is capable of supporting all of the hypothesized repeater alternatives. Considering the cost associated with an independent Mini RPV development program, it would be cost effective to utilize the proposed Army configuration if the Mini RPV is chosen as the REMBASS aerial platform.

To assist in establishing the limits and capabilities of the Mini RPV system Table 6 has been prepared describing the advantages and disadvantages of this particular system.

3.4 Manned Aircraft

This section of the report addresses the acceptability and performance of an airborne relay system based on the

use of a manned aircraft for the platform. During the course of preliminary evaluations, it was decided that only those aircraft which might be in the area for the purpose of performing some other mission, and still be capable of simultaneously supporting REMBASS, would be considered. This course of action was necessary due to the extremely high costs that would be associated with employing manned aircraft dedicated primarily to the REMBASS mission.

The performance of the most acceptable manned aircraft airborne platform alternative would then be evaluated primarily in terms of providing acceptable capabilities. The principal areas of concern are then system vulnerability and availability (both mechanical and meteorological).

3.4.1 Introduction

Present large scale operational plans include provision for a significant number of aircraft, supporting various programs/systems, to be operating in the vicinity of the FEBA. While it would appear unreasonable to require even more aircraft to be added to this scenario to support REMBASS only, it might not be unreasonable to try to obtain the benefits of an airborne REMBASS relay if this could be accomplished by utilizing otherwise wasted capacity. The existence of aircraft with sufficient additional payload capacity, operating under a mission profile compatible with the REMBASS airborne repeater requirements would be most auspicious.

The aircraft/systems operating in the vicinity of the FEBA were reviewed while considering the following requirements/capabilities.

- -- Candidate platform has sufficient additional payload and space capacities to accept the airborne relays.
- -- Aircraft/system should be designed for essentially continuous operation (24 hours per day and all-weather).
- -- Operating altitude compatible with REMBASS range requirements (essentially not less than 2,000 feet AGL).

The following aircraft/systems were considered as possible hosts:

-- OV-1D with Side Looking Airborne Radar (SLAR)

-- OV-1D configured for Infrared (IR)

-- RU-21 with Guardrail

-- Advanced Scout Helicopter (ASH)

-- OH-60A with Stand-off Target Acquisition System (SOTAS)

-- RV-1D Quicklook II

Considering the preceding REMBASS requirements, it appears that the aircraft/system most compatible with these needs is the OV-1D configured for the SLAR mission. Consequently, rather than addressing all of the possible manned aircraft platform alternatives, we will confine our attention to the OV-1D SLAR. The following sections specifically address the performance of the OV-1D with SLAR as an alternate airborne platform, however, the comments made in these sections may be considered generally representative of the performance attainable with a manned aircraft.

3.4.2 Description of Alternative

For this particular case (i.e. manned aircraft) use is made of an airborne platform primarily dedicated to another mission. The limitation to this approach is a result of the excessive costs associated with a system of dedicated manned aircraft.

The REMBASS airborne relay would be carried by the manned aircraft as a minor addition to the payload. During the course of its primary mission, the manned aircraft would be operating at sufficient altitude to enable the REMBASS repeater to "see" the deployed sensors, and be able to relay the messages to the appropriate monitors.

In the case of the SLAR mission, the manned aircraft that is used for the aerial platform is the OV-1D. The OV-1D "Mohawk" is a fixed wing, twin engine (turboprop), propeller driven aircraft with a 48 foot wingspan, normal

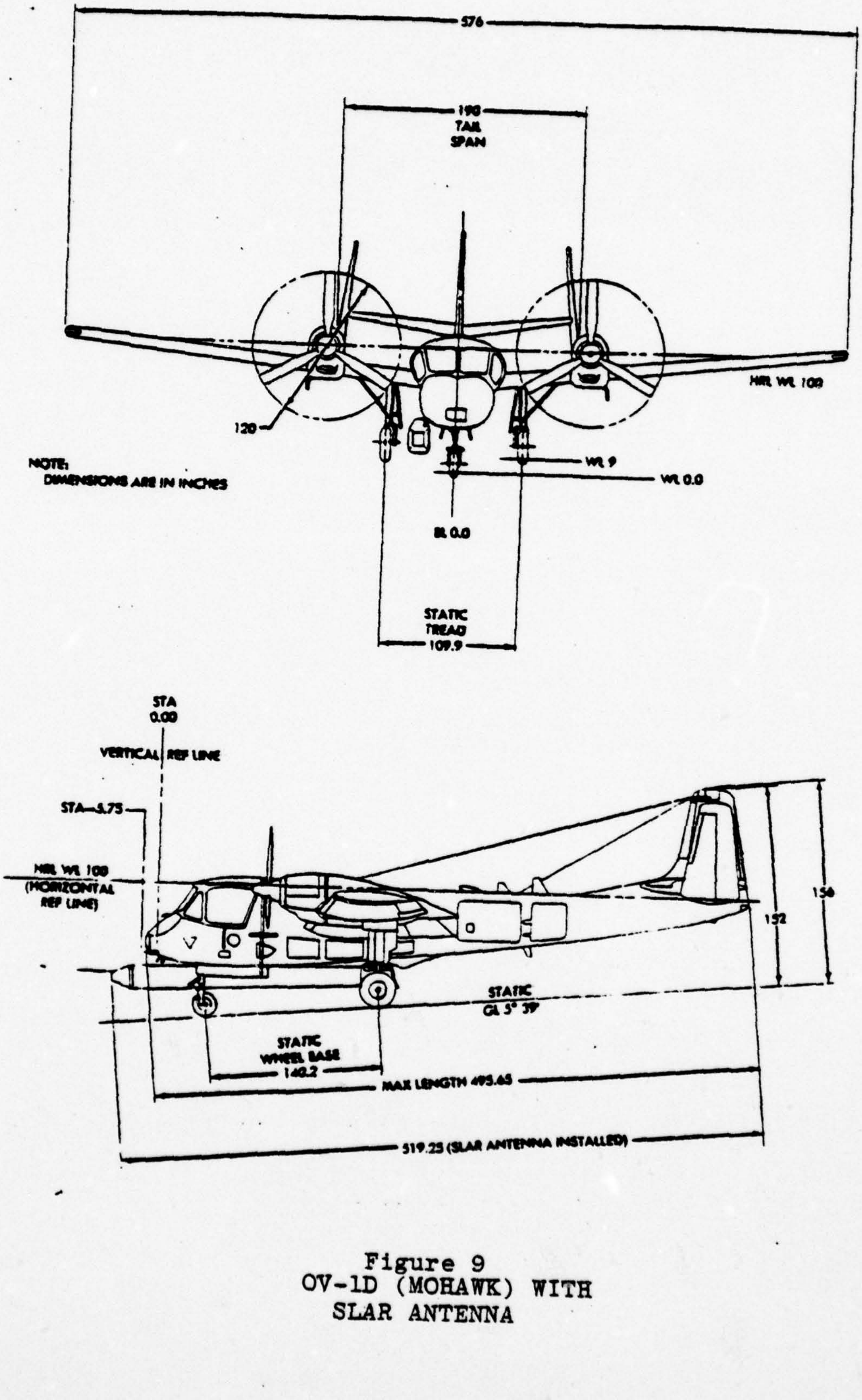

Figure 9
OV-1D (MOHAWK) WITH
SLAR ANTENNA

cruise of 200 knots, and a crew of two (see Figure 9). When configured for the SLAR mission, the OV-1D has an operational gross weight of approximately 18,158 pounds.

3.4.3 Operational Considerations

3.4.3.1 Concept of Operation

For the performance of the primary SLAR mission, 12 OV-1D "Mohawk" aircraft will be assigned to the Military Intelligence Company (Aerial Surveillance) located at the corps level. The SLAR missions will be flown with these aircraft to obtain essentially 24 hours continuous coverage. To minimize exposure of these assets, the SLAR missions will be flown with the OV-1D aircraft operating approximately 30 to 40 KM behind the FEBA, and at an altitude of 7,500 feet AGL.

This mission profile corresponds quite well with the requirements projected for the REMBASS airborne repeater. The operational altitude of 7,500 feet should be more than adequate insofar as "seeing" sensors across the other side of the FEBA, even given that the aircraft stands off 30 to 40 KM (see section 3.1.1). Further, the intention of operating continuously (with relief aircraft)over a 24 hour period would provide exactly the level of system availability needed for the REMBASS relay operation.

If the REMBASS airborne repeater is used in conjunction with the corps SLAR aircraft, certain operational problems also arise however. Due to the fact that all of the corps REMBASS sensor data (depending upon the use of an airborne platform for relay) will be funneled through a single aircraft, it may be necessary (depending upon total battalion requirements) to carry more than one large multi-channel relay. Additional relays would be necessary to provide an adequate number of communication channels (the highest number of channels per repeater considered in section 2.2 was 10).

As a further consequence of carrying all corps messages through a single point, it will be necessary to administratively coordinate the assignment of frequencies to those sensors which will make use of the airborne relay. Each battalion must insure that the sensors emplaced for long range, or obstructed, communication is set to transmit on one of the

frequencies being monitored by the airborne relay. Further, to insure no confusion between different battalions, prior agreement must be obtained as to which units will be assigned which frequencies. These frequencies, or channels, must then not be used on the remaining direct relay sensors, or by nearby elements of different corps within the monitoring range of the airborne relay. With an orbiting altitude of 7,500 feet AGL, the REMBASS relay would have a theoretical viewing radius of approximately 200 KM (roughly 125 miles), and frequency control would, of necessity, have to be maintained over a range of approximately 400 KM along the FEBA. This does not necessarily greatly limit channel availability, however, it does imply that careful consideration must be given to the problem of frequency assignment.

3.4.3.2 Payload Capacity

The maximum gross weight the OV-1D aircraft is 18,300 pounds. If the OV-1D is to carry the REMBASS repeater, while primarily performing some other mission, the additional weight of the repeater and any ancillary equipment must not cause the total aircraft weight to exceed the 18,300 pound limit.

Although all OV-1D aircraft have the same maximum gross weight limit (18,300), the total payload that can be carried is not equal for all OV-1Ds (even given the same mission requirements). This is due to the fact that OV-1D aircraft are classified as either production models or conversion models (OV-1C aircraft that have been converted to OV-1D aircraft) and there are minor airframe differences between the two. The production OV-1Ds employ a built-up wing root (which is not the case with the converted OV-1Cs) and as a result weigh approximately 300 pounds more than the converted aircraft. To insure a uniformly applicable analysis, the figures used in determining available payload are taken for the production OV-1D aircraft.

Configured for the SLAR mission, the OV-1D aircraft has a gross weight of approximately 18,158 pounds. Consequently, the aircraft should have an additional 142 pounds of payload capability before reaching the specified maximum gross weight of 18,300 pounds (OV-1D converted aircraft may have still another 300 pounds available). In addition, it appears, from the information obtained, that there are approximately four cubic feet of space available

within the aircraft.

In light of the preceding, it appears reasonable to assume that the OV-1D SLAR aircraft could support the REMBASS mission with minimum impact on the primary SLAR mission. Further, should the total corps REMBASS communications requirements exceed the capacity of the largest repeater, there would appear to be little difficulty in carrying one or more additional repeaters (especially if the more advanced lightweight repeater designs are employed) set to different frequencies.

3.4.3.3 Endurance

Under the mission profile for the OV-1D SLAR flights, the aircraft will remain on station for approximately three hours before it is replaced by another aircraft. As has been previusly noted, through the availability and use of 12 OV-1D aircraft, it should be possible to support the SLAR mission (and consequently the REMBASS mission) continuously. The factor of three hours loiter time, or endurance, is not deemed to present any significant difficulties.

3.4.3.4 Environmental Considerations

Insofar as the environmental/meteorological factors are concerned, the impact on operational availability and continuous monitoring capability with the OV-1D should be minimal. Although the ground facilities available at the aircraft base of operations may have a minor impact under very severe conditions,in general the OV-1D aircraft can be expected to perform its SLAR mission in near all-weather in accordance with AR 95-1.

While certain particular adverse weather conditions (such as severe icing conditions, severe turbulence, or extremely low visibility and ceilings) can be expected to curtail operations, it should be noted that generally if it is at all possible to operate aircraft, then the OV-1D should be available for mission support. Only for the specific case of a tethered platform (and even then certain limitations also apply) can there be expected an environmental/meteorological operational capability greater than that of the OV-1D.

3.4.3.5 Set Up/Tear Down Requirements

Because the OV-1D is capable of operating from fields at a considerable distance from the FEBA, the need for repositioning the airborne platform presents little difficulty. Also, as noted in Section 3.4.3.1, from the operational altitude of 7,500 feet AGL the repeater has a considerable range, and this could well serve to minimize the need (at least for REMBASS' purposes) for aircraft repositioning.

If, indeed, there will be any set up/tear down difficulties, they will probably be attributable to the compromise of using, for the airborne platform, an aircraft primarily dedicated to the support of a different mission. In this regard, the operational availability and responsiveness of the OV-1D platform are a direct function of the anticipated correlation with the SLAR mission requirements. If the costs of a dedicated manned aircraft support system are to be avoided, then the preceding compromise is necessary.

3.4.3.6 Detectability, Vulnerability and Survivability

Because of the secondary nature of the REMBASS mission flown by the manned aircraft platform alternative, it would be inappropriate to comparatively evaluate performance in each of these areas. The purpose of identifying detectability, vulnerability and survivability as separate categories was to enable us to obtain some measure of "mission reliability" (i.e. the likelihood of being able to successfully complete a mission). For those cases where a particular mission profile had not been evaluated in terms of "mission reliability" (i.e. REMBASS missions using RPVs or aerostats), the overall evaluation was attempted by considering each of the appropriate elements (detectability, vulnerability and reliability in particular) independently, according to the required mission profile. In the case of the OV-1D SLAR manned aircraft, however, the mission profile is that specified by the SLAR requirements, and the acceptability of the resulting "mission reliability" would have to be determined by the SLAR users, not by REMBASS.

That the Army is proceeding with plans for the OV-1D SLAR program implicitly eliminates the "mission reliability"

as a serious consideration in the evaluation of the OV-1D for use as the REMBASS repeater airborne platform. The implication here is that, despite the relatively poor performance of manned aircraft in terms of detectability and vulnerability, the provision for flying the SLAR missions at a stand-off range of 30 to 40 KM behind the FEBA will be sufficient to insure an acceptable level of survivability and "mission reliability." Should the observed "mission reliability" of the SLAR OV-1D be unacceptable, however, then the implications for the REMBASS airborne repeater availability would be most severe. If, for whatever reason, the SLAR missions are not flown, then the desired airborne platform would not be available, and the airborne repeater dependent portion of the REMBASS net would in effect be inoperative.

3.4.3.7 Maintainability and Reliability

Once again, the problems of maintainability and reliability, as they pertain to the OV-1D aircraft, are predominately the concern of the SLAR mission. It would appear that the operational requirements imposed to support the SLAR mission would insure attainment of maintainability and reliability levels compatible with the goals associated with the REMBASS airborne platform.

In the case of this manned aircraft, the overall level of performance can be divided into three categories, or elements. The reliability and maintainability levels achieved depend upon the performance of the aircraft, the SLAR equipment, and the REMBASS airborne relay.

Since our principal concern is obtaining a high level of availability, the maintainability and reliability evaluation should also include the intended mode of operation (i.e. number of aircraft alloted for mission support). The goal of the SLAR operation is the capability for continuous monitoring. Such being the case, 12 aircraft have been provided to the corps to insure continuity.

In light of the preceding, it would appear safe to assume that particular maintainability and reliability considerations should be confined to the repeater itself. The fact that the OV-1D is a standard Army item, combined with the redundancy of available systems (aircraft and

SLAR), should result in an observed platform availability that is more than acceptable.

The question of the overall REMBASS airborne platform/repeater system reliability and maintainability then reduces to a consideration of the possible impact on overall performance attributable to the interface of inherent repeater performance and the concept of employment. The use of a corps level asset, such as the manned aircraft platform, results in concentrating the REMBASS airborne repeater traffic for the entire corps through a common point. The significance here is that with this concept of operation the failure of a repeater may result not in loss of sensor data for a battalion or brigade, but perhaps for a substantial part of the entire corps front.

Due to the nature of the limitations imposed by this operational concept (i.e. small number of repeaters of many channel design), special care would be required in the design of the airborne repeaters. In order to obtain total system reliability levels equivalent to those of the alternatives employing numerous repeaters with fewer channels, the airborne repeater in this alternative would appear to require a much more advanced design, in terms of reduced weight and bulk, and substantially increased inherent reliability.

3.4.4 Cost Considerations

The procurement, operating and support costs associated with the use of a manned aircraft for the systems platform would be great enough to eliminate such an alternative from further consideration. Despite the fact that the preceding is true, however, a manned aircraft can be a viable candidate if that aircraft is already primarily dedicated to the support of some other mission.

The OV-1D SLAR aircraft satisfy the requirement for primary dedication to a different mission, and at the same time appear compatible with the REMBASS requirements for the airborne platform. The funds that could be required from REMBASS then are those associated with any minor aircraft modifications or equipment installations, and those associated with the airborne repeater. It would appear that, in terms of platform associated procurement, operating and support costs, a non-dedicated manned aircraft offers a practical minimum expenditure.

The costs associated with the airborne receiver have not previously been addressed because, to a significant extent, these costs are common to all platform alternatives. For the case of the OV-1D manned aircraft, however, the fact that the platform is a corps level asset, and not a division asset, might generate a cost perturbation worthy of additional analysis. In light of the preceding, it was deemed appropriate to include a discussion of the repeater cost impact in this section.

As previously noted, the airborne relay used with a manned aircraft may require employment of a design emphasizing increased reliability (see Section 3.4.3.7) and reduced weight and volume (see Section 3.4.3.1). The possibility exists that the development and production of such a repeater might entail costs considerably greater than those of a simpler design. The potential increase in repeater procurement costs, however, must be evaluated in conjunction with the anticipated greatly reduced operating and support costs.

On a subjective basis it appears that the expected reductions obtained with a manned aircraft would be significantly greater than the development increase. In terms of total cost to be incurred by REMBASS then, the manned aircraft alternative would seem to be a most desirable selection.

3.4.5 Conclusion

So long as there is an available platform suitable to our needs, a manned aircraft (non-dedicated) appears a most acceptable alternative. Our investigation indicates that several candidates are available which generally meet our needs, and that among these, at the present time, the OV-1D aircraft used for the SLAR mission is an almost ideal solution.

The OV-1D configured for and used in SLAR missions apparently adequately satisfies the REMBASS airborne repeater platform requirements in terms of payload capability, operational altitude and system availability (see Table 7). In terms of additional costs to be incurred by REMBASS, the OV-1D system is primarily dedicated to, and supported by, another mission resulting in the minimum requirement

MANNED AIRCRAFT

CHARACTERISTIC	ADVANTAGES	DISADVANTAGES
(1) Launch and recovery	(a) Operation from remote airfields. (b) Operation from "unimproved" fields (c) Reduced requirement for base movement (d) Near all-weather capability	(a) Requires considerable area for ground operations (b) Sophisticated airfield ground control equipment necessary in poor weather.
(2) Flight operations	(a) Flown at 7,500 feet AGL permits extended sensor ranges. (b) No remote ground control system necessary (c) Flexibility in mission area selection due to high speed capability (d) Near all-weather capability and night operation	(a) Corps level coordination of sensor channel assignment required. (b) In-flight failure of repeater may incapacitate systems for up to three hours.

TABLE 7

MANNED AIRCRAFT

CHARACTERISTIC	ADVANTAGES	DISADVANTAGES
(3) Detectability	Beyond Visual and Acoustical ranges	Susceptible to detection by radar at long ranges, and IR at shorter ranges.
(4) Vulnerability		Vulnerability to aircraft delivered weapons and possibly SAMs
(5) Survivability	Stand off range of orbit and flexibility result in high survivability	If struck, unlikely to be able to return to base
(6) Logistics	No additional aircraft support required	
(7) Maintainability and reliability	Solely repeater dependent	Higher reliability required in repeater design because of increased dependency of system.

TABLE 7

(Continued)

possible in procurement costs for the platform. Further, since the system is operating at 7,500 feet AGL, the repeaters should be able to communicate directly with all the monitors, from division down to battalion level. Combined with the fact that the manned aircraft does not require a remote REMBASS ground control station, this results in a minimal expenditure in operating and support costs.

As counterpoint to the optimized costs associated with the platform, this alternative may require a greater investment in the development of an appropriate repeater. As has been noted previously, the OV-1D alternative may require that the single airborne platform be capable of receiving and relaying messages on a large number of channels. In order to achieve this capability, within the projected space and weight restrictions, the design technology employed in the repeater may have to be of a higher level than that which would be required by a more dispersed network.

When the overall system costs are considered, however, it would appear that the potential savings in reduced platform procurement and system operating and support costs, would far outweigh any additional repeater development expenditure.

The single greatest negative aspect of this alternative is attributable to the fact that the OV-1D aircraft is a corps asset, and as such represents an unfortunate point of concentration in the network. Any failure of the airborne repeater, whether due to reliability (as discussed in section 3.4.3.7) or enemy action (attack on the aircraft or jamming), would result in a failure of that portion of the entire corps REMBASS net dependent upon the use of an airborne relay. The likelihood of any such failure, and the severity of the operational impact, are unknown at present, and are unlikely to be determined without considerable further study and analysis. It would appear, however, that in light of the alternate system applications (i.e., use of ground emplaced repeaters, or direct line of sight sensor to monitor transmission) and rapid aircraft turn around (a repeater that fails would keep the system inoperative for a maximum of three hours). These considerations should be of no very great consequence.

As previously noted, when considered on the basis of overall cost and performance, the use of a manned aircraft for the airborne platform appears a most acceptable alternative.

3.5 Miscellaneous Platforms

3.5.1 Introduction

This section of the report is devoted to a cursory discussion of platform systems which either do not fall into the previous categories, or involve a somewhat modified approach. This portion of the analysis is only briefly reported due to the fact that these platform alternatives, although they were fully considered, were eventually eliminated as being inferior to previous candidates for this particular mission application.

The following paragraphs provide a description of the additional alternatives evaluated, and a general review of the principal operational characteristics that eventually resulted in their "disqualification."

3.5.2 Description of Alternate Platform Systems

3.5.2.1 Satellite

A possible solution to providing a relay unit for the REMBASS sensors, could involve the use of a satellite. The use of a multi-channel relay on a satellite placed in a synchronous earth orbit, above the region of sensor deployment, could feasibly satisfy the REMBASS needs. In such a system, the sensors would transmit their messages to the relay orbiting above, and these would then be retransmitted down to the ground monitoring stations.

Placing the REMBASS relay on an earth satellite offers some very significant operational advantages over the more conventional approaches already discussed. On an overall basis, the operating and support requirements (in terms of personnel and equipment) for the relay and platform could be reduced to an absolute minimum. Due to the high angle of transmission (relative to the horizon) any problems associated with terrain masking could be virtually eliminated. Similarly, the high position of the repeater should enable very long sensor deployment ranges to be supportable. Finally, such a system could be expected to offer an unequaled level of availability.

Desirable as the preceding attributes may be, it is also true that a satellite-borne relay system imposes certain disadvantageous limitations. Such a system would require that appropriate satellites be placed in orbit prior to operation of the system (the number and location of the satellites would be dependent upon the anticipated world-wide theaters of operation). The problems of frequency allocation and control would probably be compounded to an intolerable level (because of the large geographical area "visible" to the relay, the utmost care would have to be exercised to insure channel availability and to minimize interference). The relay used on the satellite would require an advanced design (considerably more complicated than the designs mentioned previously in this report) resulting in a light repeater capable of simultaneous operation on a large number of channels (since a single repeater would be used to satisfy a high number of users). Further, the concentration of sensor message traffic through a single point could conceivably raise the level of enemy interest in counteracting the sensor data system (i.e. the vulnerability of the system would be raised because an attack at the point of concentration would be cost effective, whereas an attack on a widely dispersed relay network would not be acceptably cost effective). Finally, the antenna/power requirements imposed on the sensor transmitters by a satellite-borne relay are currently incompatible with the cost/operational goals of the sensor deployment concept.

From the preceding, it was concluded that the employment of a satellite-borne relay with the basic REMBASS system would probably be counterproductive. Such being the case, the use of a satellite as a relay platform was eliminated from further consideration.

3.5.2.2 Tethered Helicopter

A suitable REMBASS relay platform could feasibly be provided by employing an unmanned tethered helicopter (hovering platform). A study, entitled "Analysis of Unmanned, Tethered, Rotary-Winged Platforms", was performed for the Army Air Mobility Research and Development Laboratory by Messrs. McNeill, Plaks, and Blackburn of Kaman Aerospace Corporation. This study concluded that for certain applications, similar to those anticipated for the REMBASS sensor system, an optimal rotary-winged, tethered platform would be designed as a turbo-shaft driven synchropter fueled through the tether, from the ground.

As a possible platform for the REMBASS relay, a ground fueled, helicopter offers several desirable attributes. Such an airborne platform should provide the capability of continuous, all weather, day/night operation. Since the platform operates with a tether, the requirement for a navigation system can be eliminated, and little in the way of ground monitoring should be necessary. A platform designed as a tethered helicopter can be expected to result in a system that can be both quickly, and easily deployed and recovered. Finally, the provision for continuous fueling from the ground, through the platform's tether, should provide this type of system with the capacity for exceptional endurance.

As a counterpoint to the preceding, an airborne repeater using a tethered helicopter also can be expected to create certain operating difficulties. The inherent design characteristics associated with rotary-winged aircraft indicate that such a tethered helicopter system (with ground fueling) could be expected to involve undesirable complexity in the design of the platform and its related ancillary equipment. With regard to fueling characteristics, such a system would probably be inefficient, and might offer a significant safety hazard (due to the fuel carrying tether). Finally, the detectability and vulnerability of an essentially stationary helicopter (hovering at 2000 feet AGL) might well be unacceptable when compared with the performance of other platform concepts.

The principal benefits of employing a rotary-winged platform are that such a system can use a tether, consequently significantly simplifying guidance and control problems, and can operate from almost any available area (due to the ability to hover). Obviously, these are very desirable qualities, but the "purchase price", in terms of system complexity, is needlessly high. Using a tethered aerostat as a platform offers essentially the same advantages, while simultaneously offering an alternative that is considerably less complex. When viewed in terms of system reliability, capability and supportability, it becomes evident that a tethered aerostat would be preferable to a tethered helicopter. In point of fact, after comparing these two particular alternatives, it is apparent that the tethered aerostat dominates (i.e. is equal to, or better than, in every case) the tethered helicopter alternative. In light of the preceding, the use of a tethered, rotary-winged platform was eliminated from further consideration.

SECTION III

COMPARISONS, CONCLUSIONS AND RECOMMENDATIONS

1.0 COMPARATIVE EVALUATION OF PLATFORMS

In order to more easily review the information gathered on the competing major platform types, this data has been collected and arranged in a matrix (Table 8). For each of the principal airborne platform types (i.e. Aerostats, RPVs and Manned Aircraft) information is provided in the following areas:

(1) Payload Capability
(2) Number of Platforms Required
(3) Loiter Time of Platform
(4) Mission Reliability
(5) Operational Altitude
(6) Set Up/Tear Down Requirements
(7) Support
(8) Reliability
(9) Schedule Considerations
(10) Technical Risk Considerations
(11) Area of Operation
(12) Dedicated/Non-Dedicated System
(13) Environmental/Meteorological Considerations

AERIAL PLATFORM	PAYLOAD CAPABILITY (1)	NUMBER OF PLATFORMS REQUIRED (2)	LOITER TIME OF PLATFORM (3)	MISSION RELIABILITY (4)	OPERATIONAL ALTITUDE (5)
Tethered Aerostat	All repeater alternatives are supportable	One per Division	2 days to 1 week	High (low detectability)	2000 ft
Mini RPV (Army Concept)	All repeater alternatives are supportable	At least 2 aircraft are required per division	3 hours	High (low detectability)	2000 ft (12,000 ft max)
Manned Aircraft OV-1D/SLAR	All repeater alternatives are supportable	12 available per Corps	3 hours	High (standoff Range)	7,500 AGL

TABLE 8

AIRBORNE PLATFORM

COMPARISON

AERIAL PLATFORM	SET UP/TEAR DOWN REQUIREMENTS (6)	SUPPORT (7)	RELIABILITY (8)	SCHEDULE CONSIDERATIONS (9)	TECHNICAL RISK CONSIDERATIONS (10)	AREA OF OPERATION (11)
Tethered Aerostat	One hour for each	Set up by 8 men, operated by 2 (depends on size of aerostat 2 ½ Ton Trucks 2 Helium trailers	High	Designs exist or can be developed	Low	15-30 Km behind FEBA
Mini RPV (Army Concept)	Setup: 1 hr teardown: ½ hr	13 men 3 trucks Support equipment	High	IOC 1983	Low	15-20 Km behind FEBA
Manned Aircraft OV-1D/ SLAR	N/A	Repeater only	High	Presently Available	Low	30-40 Km behind FEBA

TABLE 8

(Continued)

AERIAL PLATFORM	DEDICATED/ NON-DEDICATED SYSTEM (12)	ENVIRONMENTAL/ METEOROLOGICAL CONSIDERATIONS (13)
Tethered Aerostat	Dedicated	Can operate in high winds. Lightning presents problem to conducting tether Heavy snowfall can terminate mission.
Mini RPV (Army Concept)	Dedicated	Restricted by severe weather conditions cannot be flown in winds in excess of 25 knots cannot be launched and recovered in winds over 20 knots
Manned Aircraft OV-1D/SLAR	Non-Dedicated	Near all weather IFR

TABLE 8

(Continued)

2.0 APPLICABILITY OF PLATFORMS

From the information provided in section II-3, it is apparent that any of the three major platform alternatives can be made to support the REMBASS mission. If a determination is to be made as to which, if any, of these alternatives is preferable, then that decision should reflect how closely the "optimal mission" capability of each alternative approaches the REMBASS airborne platform mission requirements. In this section a brief discussion is presented, on each of the three alternatives, describing an "optimal mission" type based on the inherent capabilities and design characteristics of the particular platform.

2.1 Tethered Aerostats

The principal operating characteristics of interest for a tethered aerostat are; the continuous monitoring capability (long endurance), the almost all-weather day/night operation, the low operating cost, and the relative indetectability of an aerostat at long ranges.

An "optimal mission" for a system of tethered aerostats would then appear to be one which requires the use of numerous dispersed airborne platforms capable of essentially continuous operation (24 hours per day). The platform system would be dedicated to this particular mission, and would operate in a stand-off mode.

The main costs associated with the use of a tethered aerostat system for such an "ideal mission" would be the high support costs that could be expected. Each aerostat would require its own support crew and vehicles, plus a number of additional personnel during initial launch.

2.2 Mini RPVs

The principal operating characteristics of interest for a Mini RPV are; the low cost of the system (compared to the cost of a manned aircraft), and the survivability attributable to the small target size.

An "optimal mission" for a system of Mini RPVs would then appear to be one which requires the use of numerous dispersed airborne platforms in an environment hostile to manned aircraft (perhaps even beyond the FEBA operation). Due

to limited payload capability the platform would probably be dedicated to this mission.

Such an "ideal mission" would have to accept certain "costs". The Mini RPV would require support in the form of an operating crew, associated vehicles, and a Ground Control Station (GCS). Further, there would occasionally be the added cost of a lost platform and payload. Finally, certain concessions would be required in terms of reduced operational availability.

2.3 Manned Aircraft

The principal operating characteristics of interest for a manned aircraft are; the almost all-weather day/night operation, the high payload/multi-mission capability, and the flexibility of operation (mobility to and from operating station).

An "optimal mission" for a manned aircraft would appear to be one which requires the use of few platforms, operating in a benign environment, and capable of supporting several functions simultaneously.

The main "costs" of such a mission are the operating and support costs of the aircraft system. These would either be apportioned to the multiple users, or absorbed by a single principal user. In addition, each user would probably have to accept the fact that the aircraft would represent a point of system concentration.

3.0 QUALITATIVE PLATFORM COST COMPARISON

While a detailed cost analysis was not performed for the many alternatives considered in this study, still certain generalized remarks may be addressed to the relative performance of the major platform alternatives. In this section each of the three main platform types is addressed, and the significant related cost factors identified.

3.1 Tethered Aerostats

Use of a system of tethered aerostats as the REMBASS airborne platform could be expected to result in total life cycle costs greater than would be experienced with a non-dedicated manned aircraft system, but lesser than those of a Mini RPV system. The main contributing cost factors in a tethered aerostat system are those associated with the support costs. The requirement for maintaining a ground operating crew with each aerostat will represent a considerable investment over a long period.

The additional cost factors in this alternative are comparatively less significant. Additional funds would be required for development and procurement of the aerostats and their support equipment. Based on the technology currently available the impact attributable to these factors should be small in comparison with the total life cycle cost.

Because of the payload capabilities of the aerostat, and assuming a division level operation, the associated airborne repeater would require the smallest development effort of the three alternatives.

A side benefit of this alternative is that, because of the dispersed nature of the network and the low cost of the repeater and platform, the probability of enemy action against the platform should be low. It is unlikely that the enemy would consider it cost effective to send manned aircraft or expensive SAMs against what is essentially a balloon carrying a small payload. The cost in lost aircraft or expended SAM missiles would be unacceptably high, especially considering that even if successful, such attacks would only cause minor damage to a small part of the network, and even that could be quickly repaired.

3.2 Mini RPVs

Of the three competing platform alternatives, an airborne repeater system using Mini RPVs as the platform would appear to be the most costly approach. Again, the principal cost element is the support requirement. To utilize this alternative provision would have to be made for an operational ground control station. Further, even flown to achieve maximum endurance, the Mini RPVs would require considerably greater support than tethered aerostats, particularly as a result of the many launch and retrieval operations.

Procurement and operating costs for the RPVs could also be expected to be greater than the equivalent aerostat figures, and on a total life cycle cost basis (even assuming essentially all development is already funded) it appears that RPVs would require a significantly greater expenditure. In addition, despite the greater investment, the level of performance achievable with the RPVs could not be expected to exceed (or perhaps even equal) that attainable with the aerostats, based on the REMBASS mission requirements.

To an equal degree the RPVs, if used for the platform, share with the aerostats the capacity for rendering enemy counterattack not cost effective.

3.3 Manned Aircraft

The entire viability of this alternative depends upon the existence of an orbiting platform, already dedicated to some other mission, that has the required additional payload capability and a compatible mission profile. It is extremely fortunate that such candidates do in fact exist, and among these the optimal selection appears to be the OV-1D configured for the SLAR mission.

By employing a platform already dedicated primarily to another mission, the impact of platform operating and support costs can be minimized. Given that such a platform exists, the cost of the alternative then reduces to a consideration of the required repeater expenditures. As noted in Sections 3.4.3.7 and 3.4.5, the concentration of corps traffic through a single point would generally warrant additional repeater development to insure an acceptable system reliability level. The cost of this additional repeater development (and perhaps higher procurement cost), however, would be essentially insignificant when compared with the anticipated savings in operating and support costs associated with the manned aircraft alternative.

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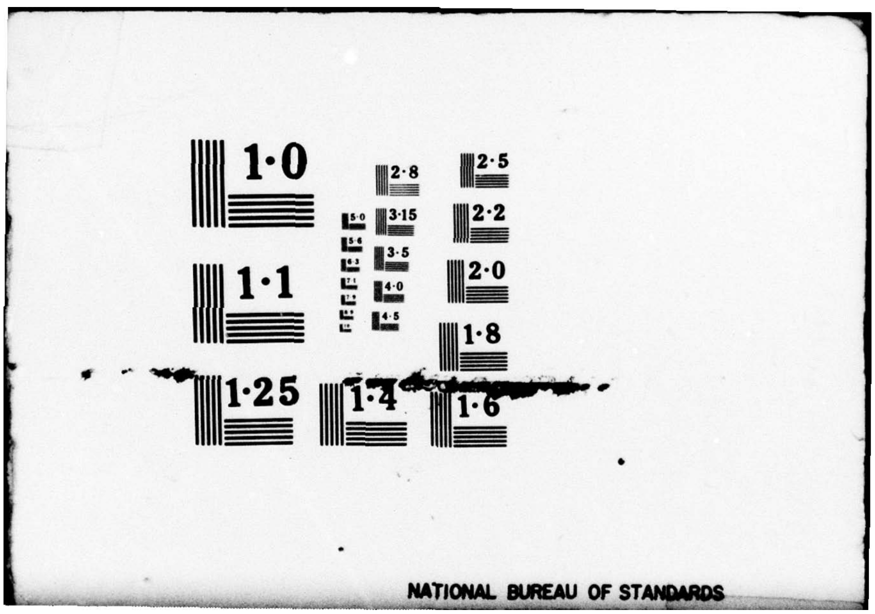
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If these anticipated savings can be realized (or even reasonably approached), then the manned aircraft platform alternative will be the lowest cost approach possible. The overall effectiveness attainable may, however, be quite another matter. The combination of dependence upon a platform primarily dedicated to another mission and point concentration of network traffic may reduce the overall effectiveness due to increased enemy interest and possible countermeasures.

This study was not intended to address the cost/effectiveness of particular alternative combinations, and generally we have refrained from doing so. We wish to note, however, that this area would benefit from further consideration, and could have significant impact in selecting the approach to be used.

4.0 CONCLUSIONS

4.1 General

The concept of employing an airborne repeater/platform to extend the transmission range of the REMBASS sensors and to overcome natural terrain line of sight limitations is a valid one. As a result of this investigative effort it is concluded that several viable approaches for obtaining an airborne repeater/platform system do exist, and that the overall concept, more than being valid, is desirable. Implementation of an airborne relay system would have a beneficial impact on the effectiveness and responsiveness of the REMBASS sensor system. Additional operational capabilities, not previously viable would become available and the overall coordination of information dissemination could be greatly improved (especially as pertains to real time transfer of data from battalion to division and vice versa).

To achieve the maximum benefit possible (and in a timely and cost effective manner) the appropriate actions should be initiated to formalize an operational plan based on the utilization of an airborne repeater. As a result of this study, it is concluded that the eventual development and deployment of an airborne REMBASS repeater system is a necessary step in attaining the full cost effective potential inherent in the original REMBASS concept.

4.2 Platform

The three major alternatives for the airborne platform are all viable candidates. It would be possible to implement an acceptable airborne repeater system using any of the alternatives, however, the cost and system effectiveness obtained would not necessarily be equivalent.

Given the basic operating requirements for the REMBASS airborne repeater, the use of a manned aircraft (dedicated to another mission) for the platform would result in the lowest total cost approach. Of the remaining two major alternatives, an airborne platform based on a tethered aerostat would involve the lesser expenditure by a considerable (although not precisely determined) amount, however, this would still be significantly greater than the manned aircraft approach. The use of small RPVs (such as the Army's Mini RPV concept) could be expected to result in the highest life cycle cost

of the three alternatives, and this is primarily the result of the considerable operating and support costs inherent in that approach.

The preceding statements presume that an acceptable manned aircraft platform will exist, and that the major portion of all operating and support costs will be borne by the aircraft's primary mission. Should such not be the case, then the operating and support costs for a system of manned aircraft would probably eliminate this approach from consideration as a viable alternative.

Regarding the effectiveness achievable with each of the three platform alternatives, the greatest potential difference is attributable to the operational concept employed. In the case of both the tethered aerostat and the Mini RPV, the platform would be a division asset, and as such would be responsible for a smaller portion of the FEBA. This then results in a more dispersed network (fewer points of concentration along the data transmission routes) and a corresponding reduction in the attractiveness of the individual platforms as enemy targets for counteraction. Further, because only division data is being handled, the platforms can operate at lower altitudes reducing the risk of sensor signal interference and greatly simplifying frequency coordination and control (between divisions).

The price of obtaining these benefits is the previously noted increased operating and support costs associated with these platforms, plus a reduction in the speed and effectiveness of data interchange between divisions.

When the airborne repeater/platform system operates as a corps level asset, as with the OV-1D SLAR aircraft, the situation is reversed. Now the operating and support costs are minimized and data interchange is quicker and more effective (because any single point can now monitor the airborne relay traffic across the entire corps front, if the equipment is available). The price paid in this case, however, is one of more complicated frequency coordination and control (between corps) and increased enemy interest in counteraction (because the entire corps REMBASS airborne repeater traffic is vulnerable at a single point of concentration).

4.3 Repeater

Based on the channel requirements and the available payload/

space limitations, the airborne repeater used in conjunction with the appropriate platforms will require a multi-channel configuration utilizing a higher level of technology than that currently employed in the single channel repeaters. This will be necessary in the case of both a division level system or a corps level system.

For a repeater/platform system that operates at the corps level (i.e., uses the OV-1D SLAR aircraft as the platform) it would be beneficial to utilize the most advanced technology avalable (despite the increased developmental costs) in order to minimize weight and volume, while maximizing channel capacity. This is made necessary by the fact that only a limited space and payload are available (the aircraft is dedicated primarily to another mission), while at the same time all of the battalions within the corps will be relying on this single aircraft for their airborne repeater data links. By optimizing the design, in terms of reduced weight and volume, the required sensor channel capacity can be obtained by carrying as many of the multi-channel repeaters as necessary.

For a repeater/platform system that operates at the division level (i.e., either a tethered aerostat or a Mini RPV) the need for advanced technology is not as great. There will be available suitable platforms capable of supporting even the bulkiest and heaviest of the multi-channel designs considered during this study. It should be noted, however, that even in this case (division level system) the smaller and lighter designs have inherent advantages. The platforms required to support the repeaters can be smaller (smaller aerostats or RPVs) for a given channel capacity if a lighter repeater design is employed, or for a given platform size, the more advanced designs provide a greater channel capacity.

In either case, corps or division, it would appear that the additional development effort associated with the more advanced designs would be justifiable. In terms of total life cycle impact, the cost of the smaller repeater designs would more than likely be offset by the benefits in operational effectiveness and flexibility.

5.0 RECOMMENDATIONS

5.1 General

It is recommended that development of a REMBASS airborne repeater system be incorporated into the goals of the REMBASS program. The additional flexibility and effectiveness provided by the airborne repeater will significantly enhance the value of the REMBASS system as an intelligence gathering tool.

It is further recommended that additional effort be directed towards developing a more detailed airborne repeater system plan of operation, to include projected battalion level system usage requirements. This data could then be incorporated in determining division and corps airborne repeater traffic levels and the related adequate channel capacity requirement.

Finally, the question of the threat to the airborne repeater system, for the case of concentrated corps communication (whether the OV-1D is used or not), should be addressed in greater detail. It is recommended that an analysis be performed specifically addressing the possibility of increased enemy interest in counteraction against a system that concentrates all corps airborne relay traffic at a single point. The study could be based on the mission profile characteristics of the OV-1D SLAR aircraft, and should address both attempts at attacking the platform and at electronically jamming the system.

5.2 Platform

Pending the results of the previously noted studies, it is recommended that the use of the OV-1D SLAR aircraft be pursued. Unless the threat analysis indicates otherwise (which appears unlikely on the basis of the information obtained during this study), the cost advantages offered make the manned aircraft alternative the most desirable solution. In addition, since the manned aircraft alternative requires essentially no development effort of consequence, even if the threat analysis eventually indicates a division level system must be used, little actual wasted effort and funds would have been expended.

Finally, if for whatever reason it is determined that a manned aircraft alternative is unacceptable, then it is recommended that the division level system eventually developed employ tethered aerostats for the airborne platform. Even the cursory cost/benefit effort performed during this study provided evidence that a system using RPVs would be significantly more costly than one using aerostats, and would provide no particularly meaningful advantages given the REMBASS mission requirements.

5.3 Repeater

In order to provide the flexibility to satisfy an as yet undetermined channel capacity, while at the same time accommodating anticipated weight and volume constraints, it is recommended that the airborne repeater employ a "hybrid" design. A "hybrid" design differs from the current REMBASS equipment in that the design involves more advanced miniaturization of electronic components utilizing more recent integrated circuit technology.

It is further recommended that the repeater utilize the "simultaneous" receive and retransmit approach rather than the queuing type of transmitter. This is based on the fact that the additional reduction in size and weight obtained with a queuing transmitter design are less significant than the incompatibility of such a design with the remaining REMBASS equipment.

The type of repeater recommended in this section (hybrid, receive and retransmit) will be compatible with whichever platform alternative is exercised.

Finally, upon approval of the airborne repeater program the required repeater development effort should be initiated as soon as possible to phase in with the fielding of the remaining REMBASS equipment.

APPENDIX A

The rate of helium leakage for an aerostat is computable from the following:

$$Q = AC_D \sqrt{\frac{10.4g \Delta P}{\rho He}}$$

where:

Q = helium loss rate (ft^3 /sec)
A = area of puncture hole (ft^2)
C_D = discharge coefficient (.6)
g = 32.2 ft/sec^2
ΔP = balloon pressurization above ambient (in. H_2O)
ρHe = density of helium (.01039 lb/ft^3)

For balloon materials the area of the puncture hole is about ½ of the projectiles cross-sectional area, due to material elasticity. Therefore, the total area of a round's entrance and exit holes is equal to the area of one round. For instance:

23 mm round - 4.47×10^{-3} ft^2
57 mm round - 2.74×10^{-2} ft^2
.22 caliber round - 2.64×10^{-4} ft^2

The tethered and powered aerostats being considered require a maximum of 2 inches of water pressurization to maintain their shape. Assuming that the pressure differential is maintained with a ballonet or a dilation panel the rate of helium loss for a single hit is presented in Figures 10,11, and 12 for 23mm 57mm, and .22 caliber ammunition respectively.

Assuming a maximum speed capability of 40 knots a powered aerostat could return from a 20 kilometer mission in 16.2 minutes. Since the effects of the helium loss would not be detected immediately, a nominal return time of 20 minutes will be used. During this time a 23 mm hit would leak 813 cubic feet of helium. This loss could probably be sustained by a 6,000 cubic foot balloon since only 13 percent of the lift would be lost. This lift loss could be readily

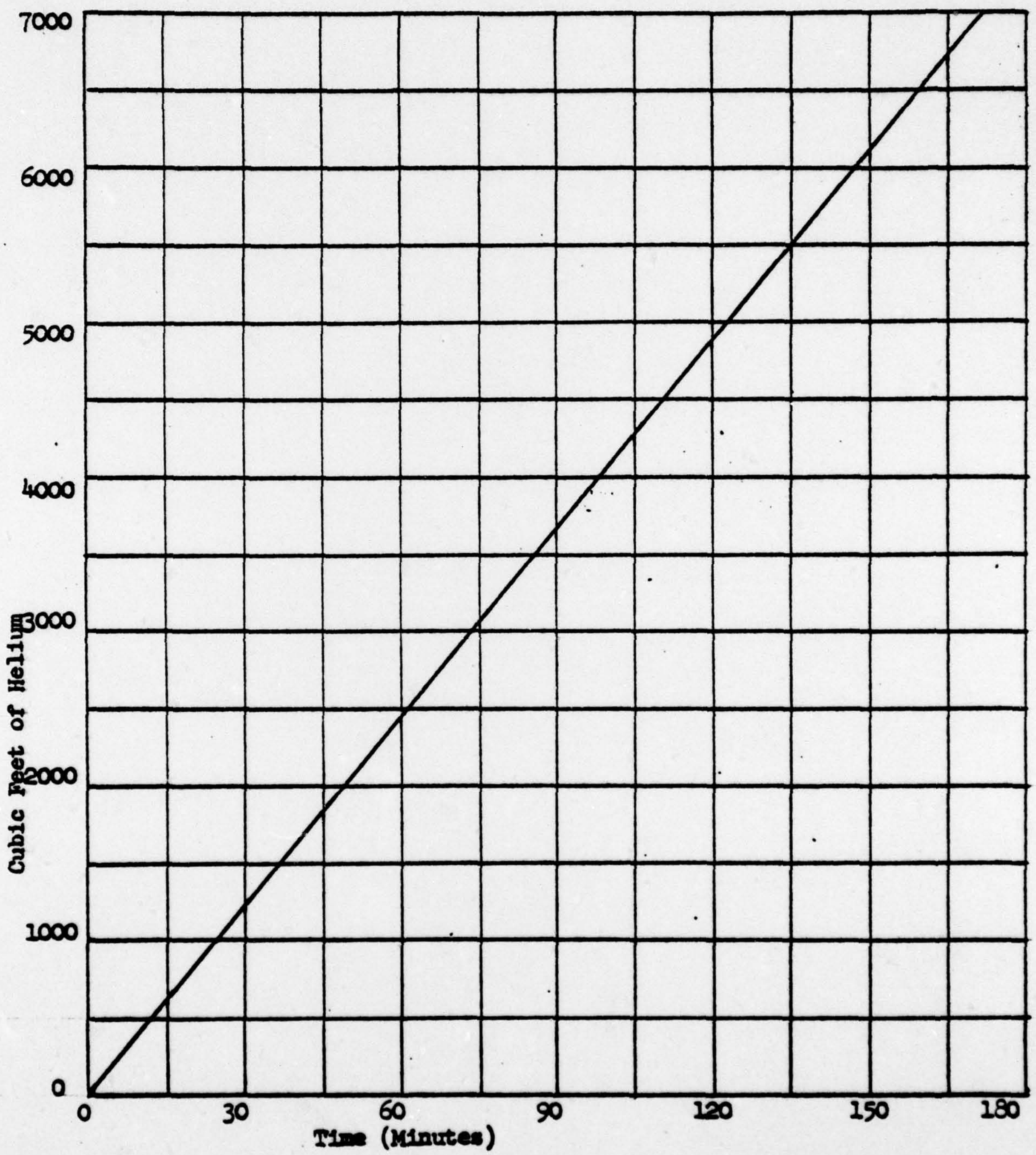

Figure 10 Helium Loss Rate from a Single 23 mm Round Puncture
(Helium Pressure - 2 in. of Water)

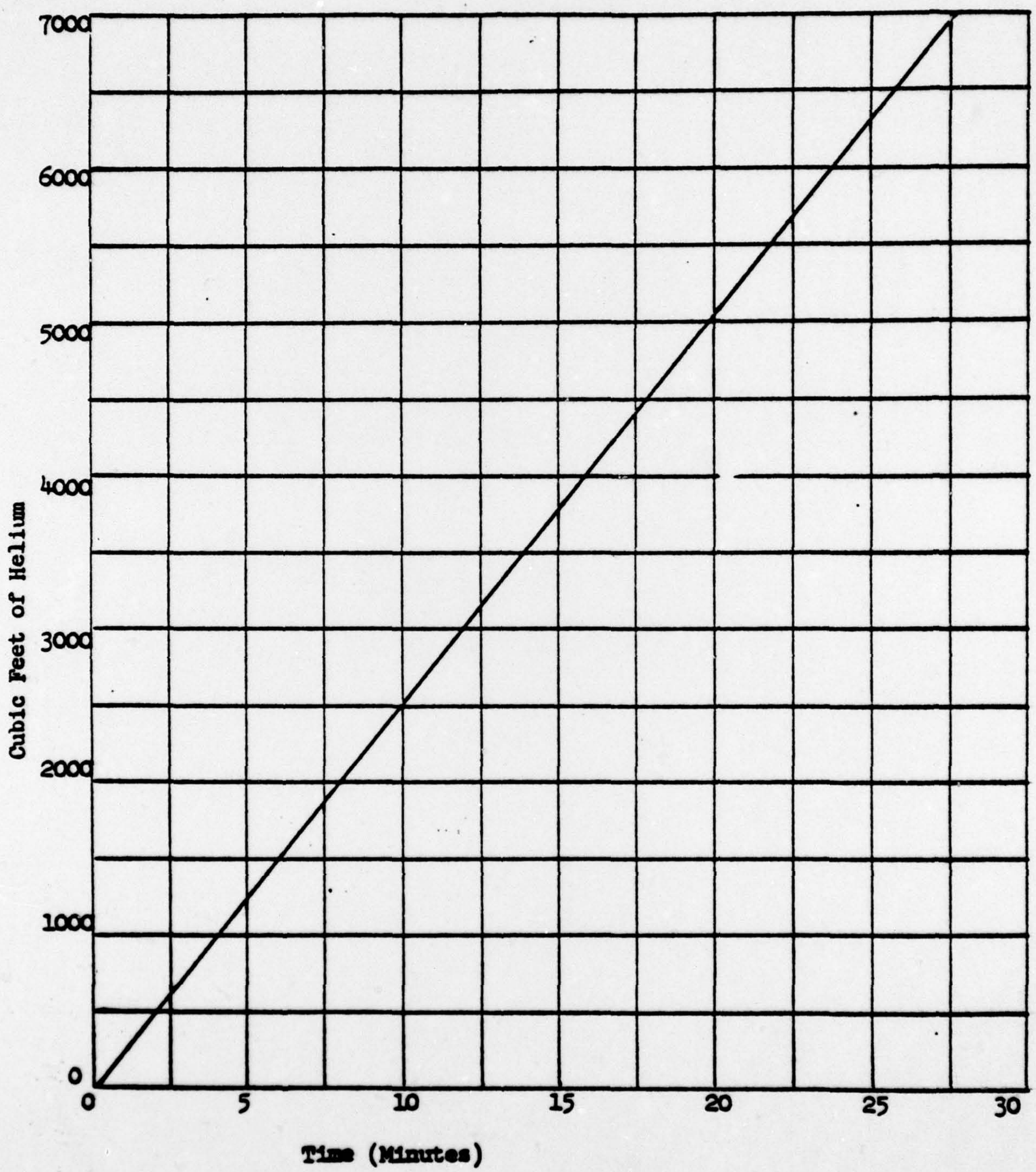

Figure 11. Helium Loss Rate from a Single 57 mm Round Puncture (Helium Pressure - 2 in. of Water)

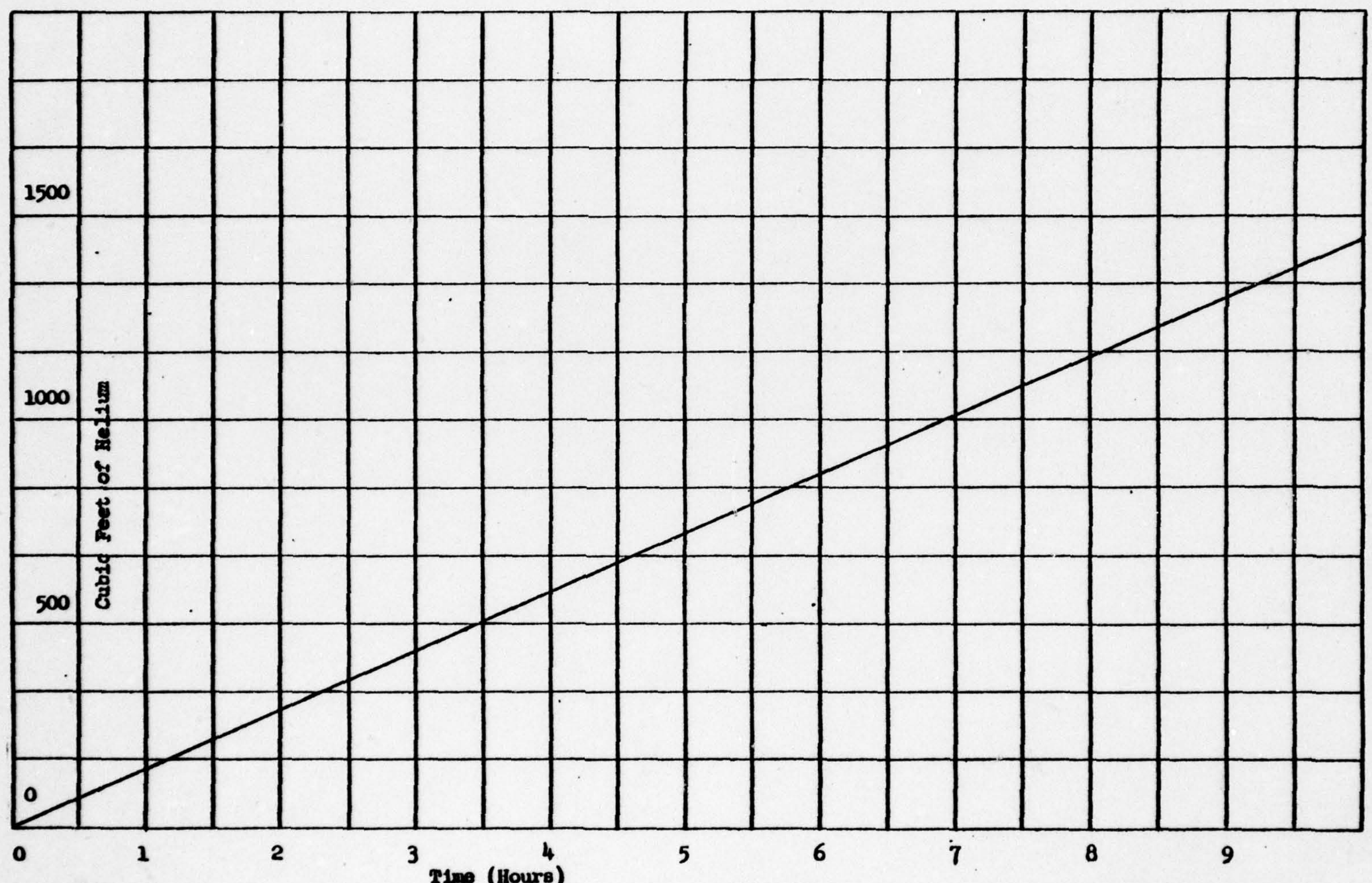

Figure 12. Helium Loss Rate from a Single 22 Caliber Round Puncture (Helium Pressure-2 in. of Water)

countered with aerodynamic lift. A single quad -23 hit, however, would be unlikely due to the weapon's high rate of fire. A five round hit would produce a 65 percent lift loss before the balloon could return to base. This magnitude loss could not be sustained without a loss of the aerial platform.

In twenty minutes one 57 mm round hit would cause a 5,000 cubic foot helium loss (83% lift), which would also be unsustainable. It must be concluded that a powered aerostat carrying payload (approximately 6,000 cubic feet) could not sustain 23 or 57 mm hits and successfully return to base.

The information provided above was extracted from ECOM Research and Development Report #4499 titled "Remotely Controlled Balloons for Border Surveillance - A Feasibility Study."

REFERENCES

1. "Tethered Balloon Antenna System ", IM-11 5985-32 8-15 DS, GS and Depot Maintenance Manual.

2. "Analysis of Unmanned, Tethered, Rotary-Wing Platforms", AD-785-581.

3. "Aerial Platform Programs, Volume I, Balloon", AD BOO 7792L.

4. "Aerial Platform Programs, Volume II, Remotely Piloted Helicopters", AD BOO 7793L.

5. "Family of Tethered Aerostats", Sheldahl Corporation.

6. Technical Brief and Program Plan "Tethered Aerostats For Tactical Applications", Sheldahl Corporation.

7. "A System to Improve Battlefield Surveillance and Target Acquisition", Sheldahl Corporation.

8. "Tethered Aerostat Systems and Other Inflatible Structures", Sheldahl Corporation.

9. "Miniature Multipurpose Remotely Piloted Vehicles", Melpar Division, E-Systems Inc.

10. "Remotely Controlled Balloons for Border Surveillance, A Feasibility Study", ECOM TR-4499.

11. "Potential RPV Platforms for U.S. Army REMBASS", Analysis Devel Science Inc.

12. Surveillance VTOL-RPV System, Canadair CL-227.

13. "Aeronautical Mini-RPV Program", ASTM-77-5B Teledyne Ryan Aeronautical.

14. Letter Reports (Platforms):

    ASH Characteristics (C)
    OV-1D Aircraft Characteristics (U)
    RV-21 " " (C)
    RV-1D " " (C)
    Harrassment Drone Characteristics AF (S)
    Miniature Drone Vehicles AF (S)
    U.S. Army Mini RPV Concept (C)

15. "Propagation Above 30 Megahertz Line-Of-Sight Conditions", Reference Data for Radio Engineers.

16. "Multiple Exray System Tests at Camp Pendleton, California (U)", SC-DR-72 0034, Sandia Corporation.

17. "Data Link Validation Program Final Report", CS&TA Laboratory, ECOM.

18. Letter Report: "Multichannel Repeater Physical Characteristics", RCA, Burlington, Mass.

19. Letter Report: "Multichannel Repeater Battery Requirements" and "Multichannel Repeaters Physical Characteristics". Resdel Engineering Corporation, Arcadia, Calif.